The Ottawa Carleton Educational Space Simulation

OCESS

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LISGAR

OTTAWA-CARLETON
DISTRICT SCHOOL BOARD

The Ottawa Carleton Educational Space Simulation

The Ottawa Carleton Educational Space Simulation (OCESS), otherwise known as spacesim, is a student-run organisation devoted to educating its members about space and space exploration through an elaborate simulation program. The student members also gain valuable experience through the educational services that the organization provides to other schools and community groups in the form of space science workshops (Elementary Education Program (EEPs)), elementary and highschool planetarium presentations (we own a StarLab© portable planetarium), and a space science contest. The sale of these services provides some of the club's funding. The club is based at Lisgar Collegiate Institute and runs under the auspices of the Ottawa Carleton District School Board, but it is open to any highschool student in Ottawa Carleton area. The primary work area is a shop room at the Albert Street Education Centre (440 Albert St.), but the club has office space at Lisgar Collegiate as well.

This organization is entirely run by its student members. The student members set the goals and the strategies to meet them, choose a leadership team, carry out all of the tasks, and manage all of the educational services of the club. The teacher advisor supervises all activities, provides advice and suggests strategies and procedures to follow, acts as a liaison between the group and the school board, and ensures that a safe and welcoming environment exists for all of the members.

This organisation meets a need for engaging, hands-on instruction in astronomy and space exploration for members as well as non-member students and teachers. It provides a focus for students to apply skills in math, physics, chemistry, geology, biology, art, trades skills, and computer science toward the solution of practical problems. It also provides students with simulated and hands-on experience in the activities and planning involved in space exploration. This is an important field of endeavour for Canada, but one that is remote from the day-to-day lives of most students. Finally, like sports teams and student government, the OCESS provides students an opportunity to take on leadership roles and to work co-operatively with other students towards a shared goal.

The Main Mission: Astronauts, Mission Control, and Simulators

Our main activity each year consists of a simulated mission to another celestial object. This is a 120-hour long procedure in which 6 student astronauts spend the entire time within a mock-up of an interplanetary spacecraft at the Albert Street site. The only time that they emerge is to explore and collect samples from a mock-up planetary surface at their destination. Other students carry out mission control duties: communicating with the astronauts through radio, closed circuit video, telemetry software, and computer text communication. They assist the astronauts in their duties, help solve emergencies as they arise, and take part in analysis and planning activities. Mission control usually is situated in the spacesim office at Lisgar Collegiate, but can run from the backup MC at Albert Street. A third group of students is the simulators who build the planetary surface; cause various events, emergencies, and malfunctions; and ensures that the other two groups stay within the bounds of the simulated reality. They sneak about the planetary surface and exterior of the spacecraft, but have a space of their own in a special balcony overlooking the rest of the room.

The simulation process has two components. The physical component consists of the spacecraft, the planetary surface, and the mission control room. The computer simulation component consists of 10 computers networked together in a private local area network, each running one part of the simulation.

Physical Simulation: spacecraft

The spacecraft structure has 6 compartments totalling 37 square metres. It is a steel stud/drywall construction with an independent plumbing system and mains electrical service. It contains all of the computer, networking, and communications equipment needed to carry out the mission. It has numerous functional and non-functional spacecraft equipment, most of which can be monitored by the simulator students. Functional equipment is integrated into the computer simulation and affects the performance of the simulation. The spacecraft also contains bunks; kitchen facilities; toilet facilities; an airlock with EVA suits; repair equipment, materials and spare parts; a lab space with equipment to collect, store, and analyse samples; and a closed-circuit camera system used both for communications as well as for monitoring by the adult supervisor.

Physical Simulation: planetary surface

The planetary surface is constructed by the simulators through the first half of the school year in secret from the astronauts and most other students. All student members take part in the choosing of the destination based on what might be found there and what goals can be addressed by going there (and the coolness factor, to be honest). They then decide what they are likely to find there, what they hope to find in detail, and what experiments they want to carry out. The simulators take all of this research and sets of goal statements and decide what their constructed planetary surface should look like, how they are going to construct it, and what items of interest it should contain. The basic construction process is much like that which is used on a major movie set. A wall stud frame is constructed and covered with chicken wire folded into an approximation of the landforms to be built. This is covered in strips of aluminum foil coated in fast-setting sheetrock compound. Once this sets up, it is coated with more detailed structures made of sheetrock compound and pigment as well as sand, rock, mud, volcanic debris, etc. as is needed. These are patterned to mimic the geological and biological features that ought to be there. The planetary surface is larger than the interior of the spacecraft and takes an enormous amount of planning and work to pull off in time for the mission.

Computer-based Simulation
The computer component of the simulation is a set of in-house software applications (totalling over 15,000 lines of code), running on separate computers, that manage different aspects of the mission. The orbit application manages the motion of bodies within the solar system as well as the motion and piloting functions of the spacecraft. The engineering application manages the generators, electrical power distribution systems, and all devices on the spacecraft such as engines, radar, navigation, reactors, batteries, thrusters, cooling systems, etc. The orbit application's piloting functions work or fail to work based on how the engineering software is managed. Many of the inputs to the engineering application come from external devices and switches within the spacecraft. The EECOM application manages the environmental systems on the spacecraft, such as the pressures of various atmospheric gases in each compartment; the state of the doors connecting compartments; supplies of pressurized gases; radiation levels within and outside of the spacecraft; dust, pollutants and other contaminants in each compartment; and the state of EVA suit air bottles while in use or in storage. Several components of the EECOM application take inputs from the engineering application and the reverse is true as well.

Each of these software applications has one or more counterpart applications running in mission control to monitor it. This allows the mission control team to monitor and assist the astronauts during the mission. There also are counterpart applications running in the simulator section which allow the simulators to monitor the state of the simulation, enact a multitude of different malfunctions and mission events, and automatically record the state of the simulation at regular intervals for training.

Running the Mission
The computer simulation is integrated into the physical one via a set of digital interfaces: door sensors, a set of control panels, and various other switches and mock equipment. Thus, both components of the process function as an integrated system during the mission. The mission activity requires that students learn all of the skills needed to carry out a real space mission: actually piloting a spacecraft, managing a power distribution system or environmental control system, putting on and working in a bulky EVA suit, or carrying out geological measurements, geological sampling, and chemical experiments. Failure during the mission always is a possibility and will be obvious to all who are participating.

Mission Preparation
Most of the year is spent preparing for the mission and carrying out our educational outreach activities. To accomplish all of this, the organization is broken down into a variety of task forces. Mission preparation requires research into the intended destination, developing a rational for the mission, experiments to conduct during the mission, planning supplies that must be taken, upkeep on the spacecraft and related systems, training on the flight, engineering, and environmental simulation software for the spacecraft, mission control, and simulators, and training on mission procedures such as collecting samples while wearing a spacesuit. Students also must plan each phase of the mission profile (transfer orbits, supplies of fuel and other consumables) to ensure that the spacecraft will successfully arrive at the destination and return to Earth. Several smaller training missions are carried out before and after the main mission.

Work Sessions
There are two meetings each week. A planning meeting takes place each Friday at lunch at Lisgar Collegiate. This is when plans are finalised for the work session that evening and for future activities. Lists also are made of what materials must be obtained to carry out those plans.

The main work sessions take place on Friday after school at 440 Albert St. Students start arriving at 3:30 PM and the sessions last until 10 PM. A wide variety of activities take place at work sessions. Each is lead by a senior student. Most of what is done consists of preparations for the main mission (research, designing and building planetary surfaces, training on flight and engineering software and hardware, making mission profiles and schedules) and also repairs and upgrades to our spacecraft mockup, computer systems, EVA suits, electronics, dry wall, cleaning up and organizing supplies etc. One of the best aspects of this club is the wide range of activities that it involves. Some of the useful skills that students learn include how to install and repair drywall, how plumbing and electrical systems work, and how to build, run, and troubleshoot computers and computer networks.

Attendance at the Friday lunch meeting and Friday work sessions is not compulsory. The Friday evening work session does take place on school-board property, it always is supervised, and all student codes of conduct are followed.

Educational Services

Educational outreach activities require students to manage bookings from other schools, ensure that club members are properly trained to give presentations, and to co-ordinate presenters for each booking. Students also must ensure that all of the supplies and equipment needed to run the presentations are ready. EEPs and planetariums are presented by student members. By delivering these educational services, the student members become much better versed in the relevant curriculum expectations than they would be if just learning them in class. They also develop self confidence and speaking skills. The Galileo Challenge has been offered to science students at all schools in the Ottawa region. Student members write the contest exam, co-ordinate the advertising and other communication with schools, distribute the tests, and obtain prizes from local businesses. Student members also co-ordinate guest speakers such as Canadian astronauts and pilots.

Planetariums

The Starlab planetarium is an inflatable dome with a projector. It accommodates a typical class of students. The OCESS has developed a presentation for both grade 6 and grade 9 science classes, each of which addresses many of the significant curriculum expectations for the respective grade level.

Elementary Education Program

EEPs are a series of interactive space science presentations delivered to small groups of students from a single class. Groups are cycled through each of the presentations over the course of a day. Depending on time and grade level, an EEP session can involve all or some of the following presentations:

1) Newton’s laws and how they affect working in space.
2) Rocketry and Orbital mechanics
3) Electrostatics and spacecraft propulsion
4) Modelling motion and phases of celestial objects as seen from earth
5) Tour of the solar system: physical characteristics of planets and other bodies
6) Scale physical model of the solar system
7) Planetarium presentation
8) Problems and solutions relating to communications in deep space
9) Observation devices and how they work (telescopes and pin-hole solar viewers)
10) Mini-mission activity using OCESS spacecraft systems
11) Satellite design contest

Stations 1 to 6 involve smaller groups from the class which cycle through the different presentations in 30 minute time blocks. Stations 7 to 11 involve the whole class.

Program Summary

The spacesim program is a year-long process involving approximately 500 hours of teacher-supervised activity per year. There also is considerable time spent in independent work at home and at school. During this time, students engage in and are exposed to a wide variety of different activities, skills, training, and research. As a result, a large number of the curriculum expectations from the Ontario Secondary Curriculum can be addressed in the process of participating in the program (see Appendix).

The program allows students to set their own goals in the process of addressing these curriculum expectations. The level of student investment in the process is maximized by the fact that failure is a real possibility and will have real consequences to the success of their mission. The planetary surface or shipboard systems may or may not be ready in time and may or may not function properly. Pilots or engineers may or may not make fatal mistakes in carrying out their jobs. Most important, however, students learn to see failure as something that can be recovered from and learned from. Things always will go wrong, but there always are alternatives to be explored if this happens. They learn to recognize when playing it safe is essential and when risk-taking is appropriate and valuable. They also learn to carry out their activities with the expectation that things might go wrong and to have a plan for that. In this way, they become more personally responsible for their actions, to their benefit in later life.

Equally important, students are encouraged to be tinkerers. They can take computers and other systems apart and see how they work at their most basic level. Unlike a school lab activity, we have months in which to restore equipment to working order. This sort of discovery learning allows students to see past the black-box aspect of modern technology and instills in them the confidence and curiosity needed to become successful engineers, scientists, and informed citizens.

Spacesim is an extracurricular activity. The ultimate success of each mission or presentation is its own reward. Spacesim represents the ideals of student-centred, goal-oriented education. Curriculum expectations are addressed as in a regular course, but they are remembered more consistently and for a longer time because they are part of process that is intrinsically important to the students. This is the key to spacesim’s more than quarter century of success.

Human exploration of space will continue and become more important to society. It is critical that a significant proportion of the voting public appreciate not only its value, but also its costs, dangers, and limitations if society is to properly direct the progress of these endeavours. This is spacesim’s purpose.

Appendices

APPENDIX A: FIGURES

1) Mission Student Groups

1a) Astronauts

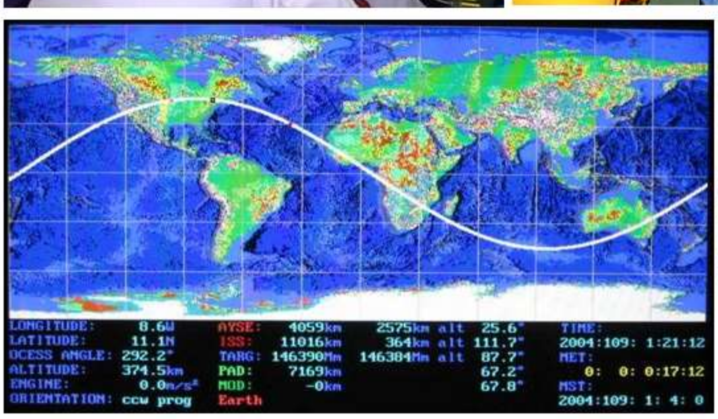






1b) Mission Control





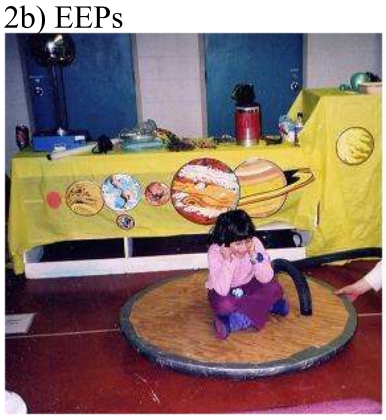
1c) Simulators



2) Educational Activities

2a) Planetariums

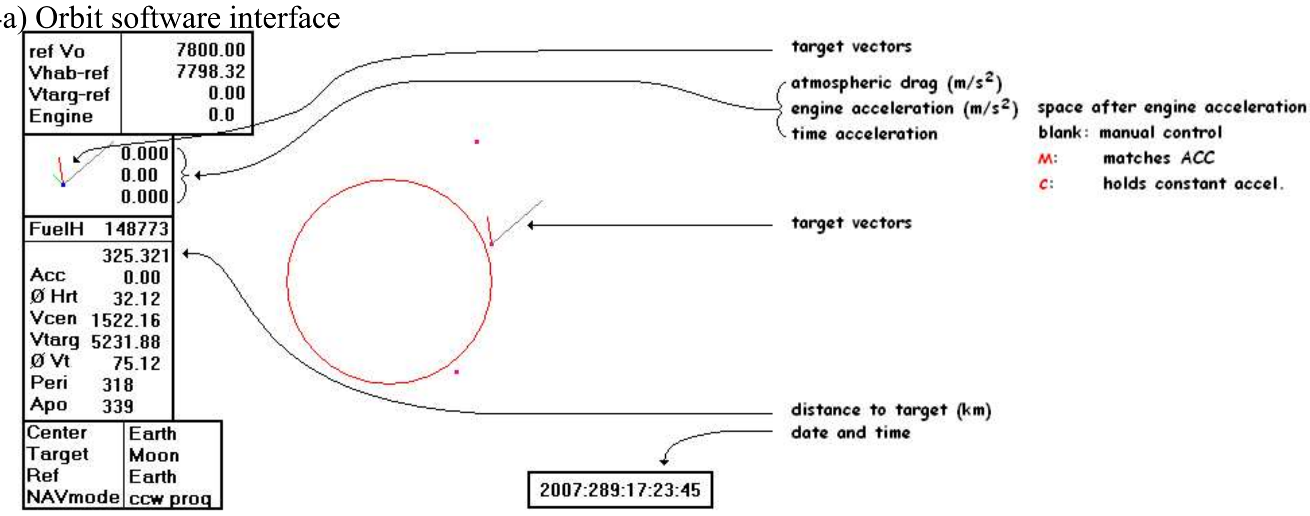
2b) EEPs



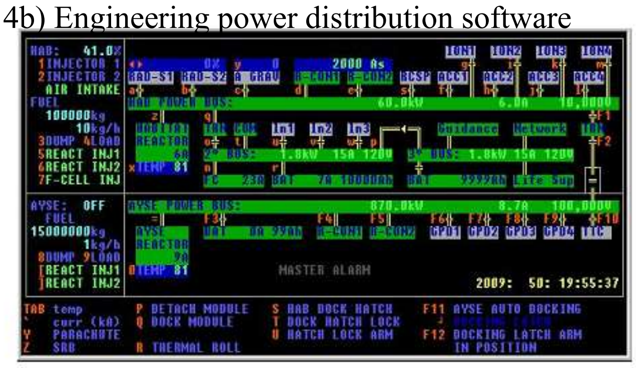
3) Training

4) Mission Software

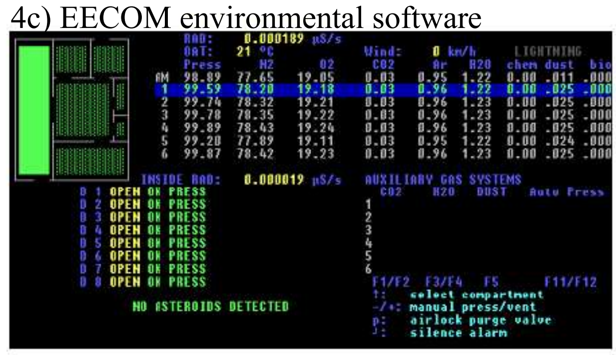
4a) Orbit software interface



4b) Engineering power distribution software

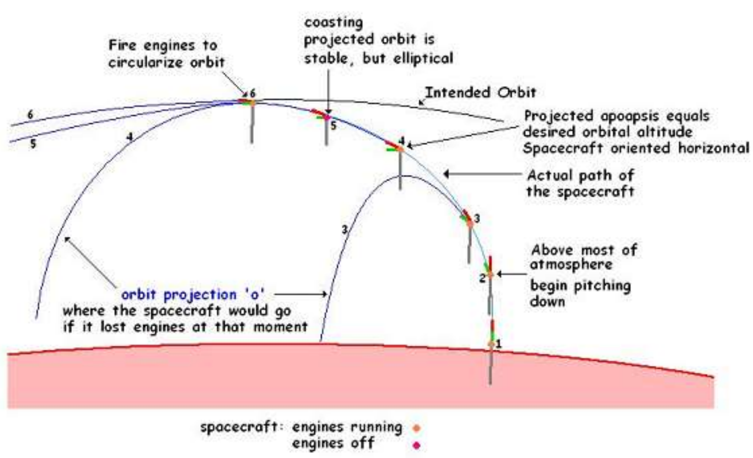


4c) EECOM environmental software

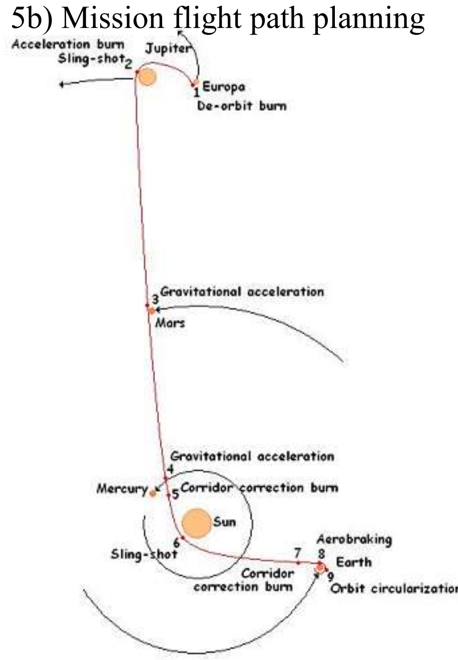


5) Mission Preparation

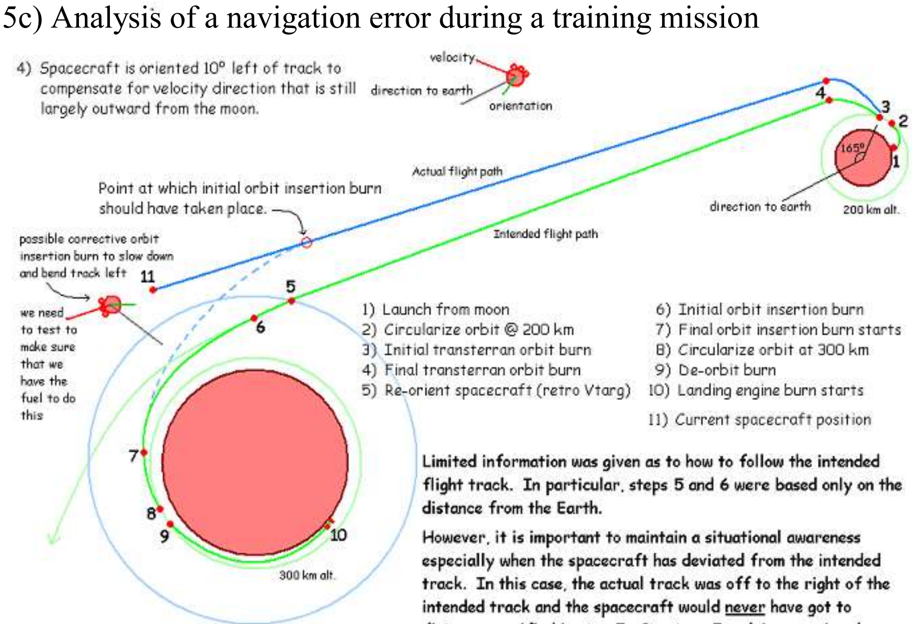
5a) Training on specific components of the mission flight path



5b) Mission flight path planning



5c) Analysis of a navigation error during a training mission

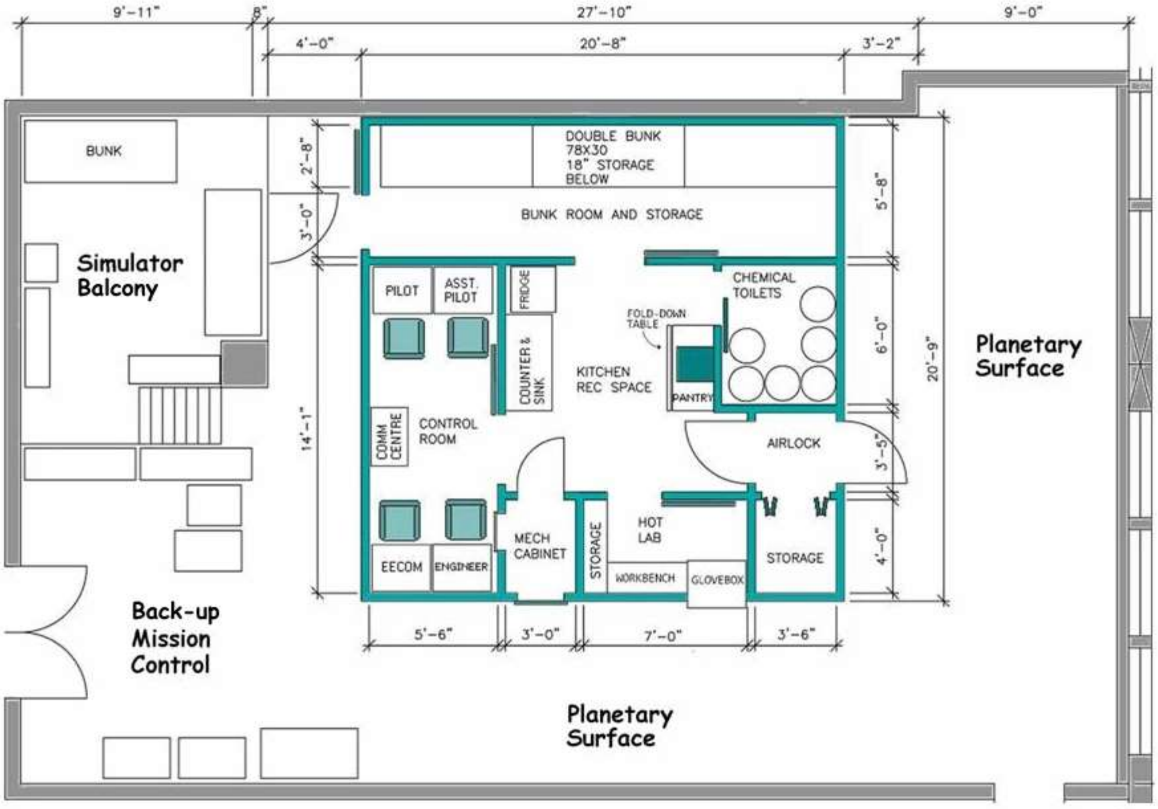


The initial engine burn to leave lunar orbit is too long. The significance of mistake is not recognised at the time. The transfer orbit to earth is not on the intended track.

The criterion used to time the earth orbit insertion burn is never reached on the actual track so the engine burn time is missed.

The lesson learned was to ensure that fail-safe criteria are used to time mission-critical events.

6) Albert Street Room Layout and Structures



Spacecraft interiors under construction.

bunk room

kitchen

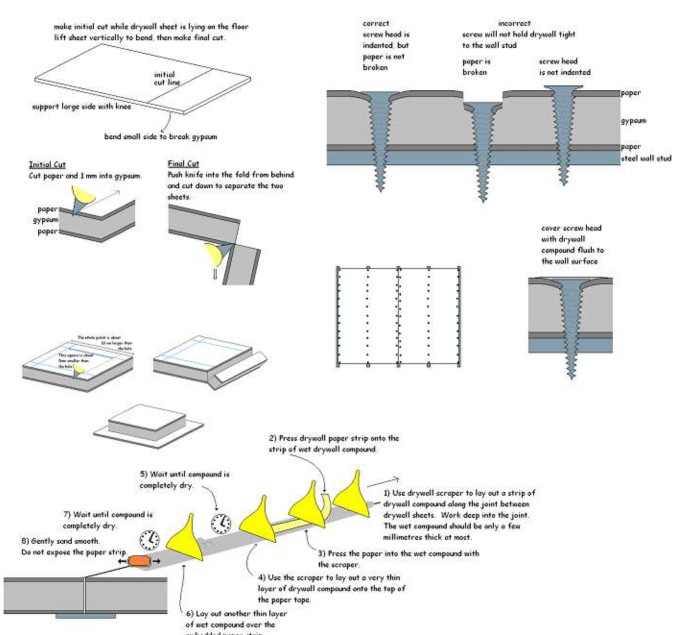
air lock

control room

control room with control panel under construction

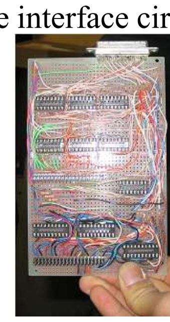
hot lab with glove box

drywall installation and repair training



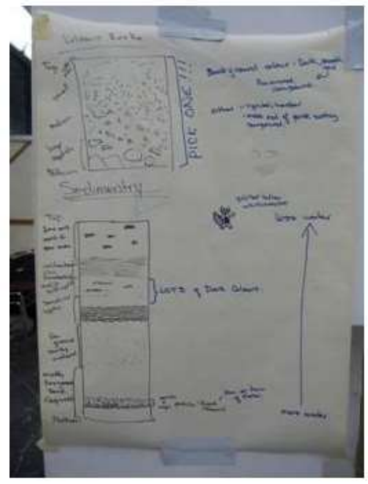
asteroid impact damage

hardware/software interface circuitry



7) Planetary Surface Construction





Planetary surface examples: 2012 surface of Mars, 2015 interior of a cave on Hyperion, a moon of Saturn, and 2017 surface of Mars.





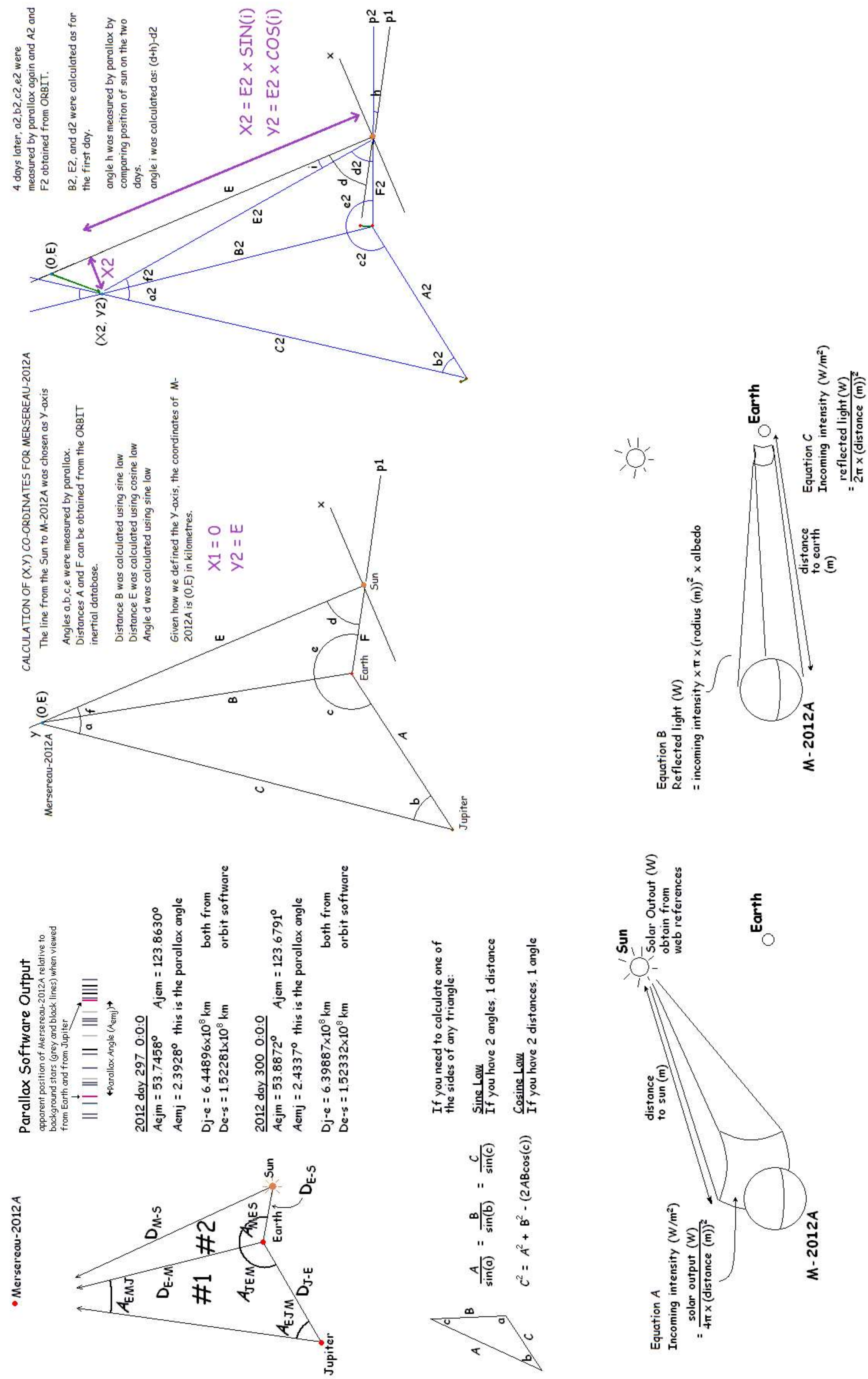





Appendix A

8) Problem Solving

An astronomy problem solved as part of the 2013 mission: deduce the distance, velocity, and size of a rogue planet (designated Mersereau-2012A) so that an intercept mission can be planned.

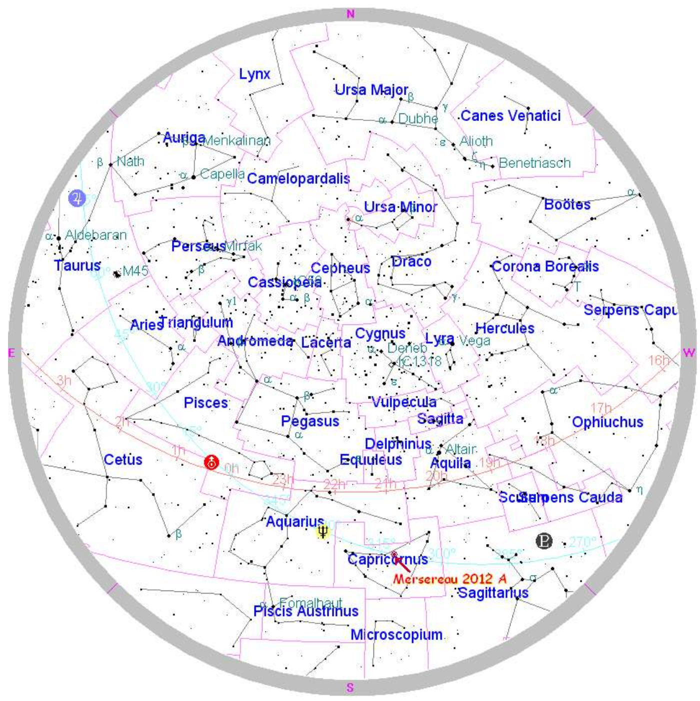


APPENDIX B: SAMPLE MISSION GOAL STATEMENTS

1) 2013 Mission to MER-2012A

Ottawa Carleton Educational Space Simulation
News Release
October 10, 2012

An anomalous object, designated ***Mersereau-2012A***, has been detected in the constellation Capricorn by OCESS member Alex Mersereau. The brightness of the object and high rate of closure speed suggests that the object could be a "rogue" planet (a planet moving though space independently of any solar system).



A study of Mersereau-2012A has been chosen as the focus of the 2012/2013 OCESS mission. This could be our first opportunity to study a planetary body from another solar system and the interstellar material that it might have accumulated during its travels. If the object's path and velocity are such that the OCESS spacecraft can make an intercept, it may be possible to attempt a landing.

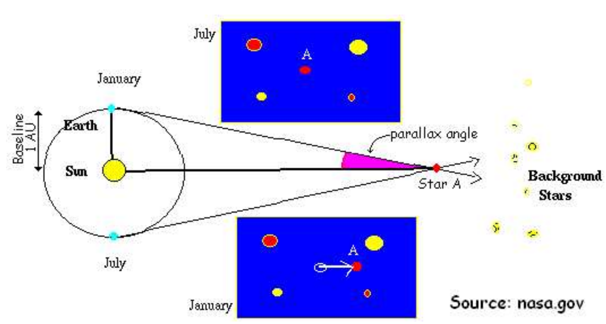
While it is possible at this stage that Mersereau-2012A might pass close to or collide with the Earth, the likelihood of this is very small. However the Jupiter system of moons and the asteroid belt also are possible targets for a close pass. These could offer an opportunity to study the effect of a moving gravitational field on a moon or asteroid. Perhaps a perturbation of the orbit of one of these solar system objects, similar to that which ejected Mersereau-2012A from its original solar system, could be observed. The next month will be spent gathering and analyzing data to plan a mission to closely observe and perhaps land on Mersereau-2012A as it passes through the inner part of our solar system.

Current Location

Mersereau-2012A is approaching the solar system from the direction of the constellation Capricorn. The current location - direction and ***distance*** - of Mersereau-2012A cannot be precisely fixed from data collected on earth or earth orbit. However, the following are pertinent to a rough estimation of distance as will be carried out by the OCESS astrometric analysis team:

1) a) The object's closure speed is quite high (see below)
   b) The object's reflected apparent brightness has not changed significantly over the past 10 days. The brightness of reflected solar light that we see from a distant object is proportional to $1/\text{distance}^4$. Therefore, the ***rate*** at which brightness increases itself changes as the object nears the earth.
2) The object's apparent brightness is high compared to Kuiper belt objects.
   Reflected brightness is a function of three variables:
   a) radius of the object
   b) albedo of the object; the percentage of incoming light that gets reflected back
   c) the distance to the object
   If reasonable estimates of the first two can be made, then an estimate of the third can be calculated.

A better estimate of the current distance to the object can be obtained by ***long baseline parallax*** measurements (the apparent difference in an object's position against the background stars when observed from two different locations).

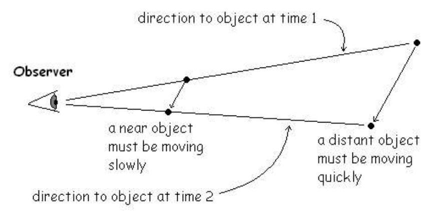


An Oct. 5th OCESS mission to the L2 Jupiter Lagrangian point (one of 5 gravitationally stable points around any planet at which a spacecraft can be parked) to deliver a satellite telescope to establish a baseline for simultaneous parallax observations had to be scrubbed after difficulties were encountered on docking with the orbiting main drive unit. This mission will be attempted again on Oct. 12th. Simultaneous observations are needed as the location of the object is changing rapidly due to its high closure speed.

Velocity

Reflected solar light from Mersereau-2012A exhibits a blue-shift, indicating that the object is moving towards earth at high speed. Analysis of the blue shift by the OCESS astrometrics team will determine the actual closure speed.

The object also exhibits a small, but significant tangential speed as evidenced by a parallax shift against the background star-field (an apparent angular velocity relative to the background stars). Further analysis must be conducted to determine what component of this shift is due to earth's motion around the sun and how much is due to the motion of Mercereau-2012A relative to the sun. In addition, the actual tangential velocity relative to the sun cannot be computed from the apparent angular without knowing the distance to the object. A given angular velocity could be cause by a slow rate of motion if the object is at close to the observer or a very high rate of motion if the object is more distant.



Until the actual tangential component of Mersereau-2012A is known, it will not be possible to predict its path through the solar system and plot a mission to intercept it.

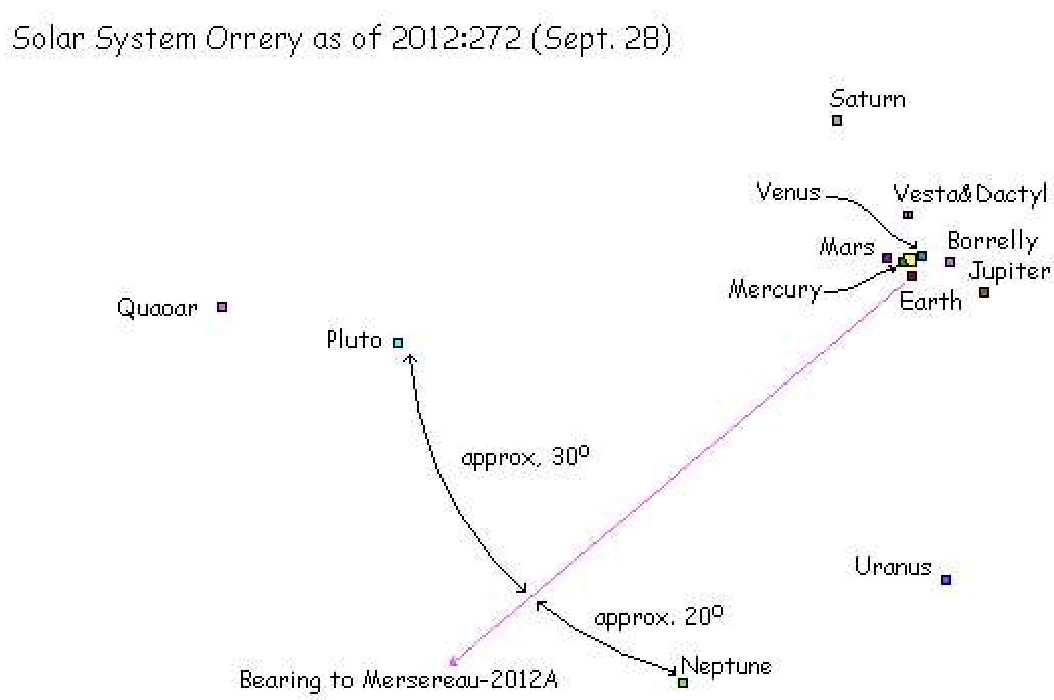
<u>Short-term Goals for Data Gathering and Analysis (days)</u>

1) Calculation of closure (centripetal) speed from blue-shift data.
2) Determine distance to M2012A a) first by estimation
   b) later by parallax observations
3) Calculation of M2012A tangential speed from angular motion, distance, and Earth's motion around the Sun.
4) Estimate the size of M2012A from distance and estimated albedo.

<u>Medium-term Goals (weeks)</u>

1) Calculate the path through the solar system and determine the feasability of an intercept and landing.
2) Evaluate the potential for undertaking a robotic reconnaissance mission (fast close pass or intercept and orbit which requires much more on-mission fuel).

<u>Long-term Goals (months)</u>

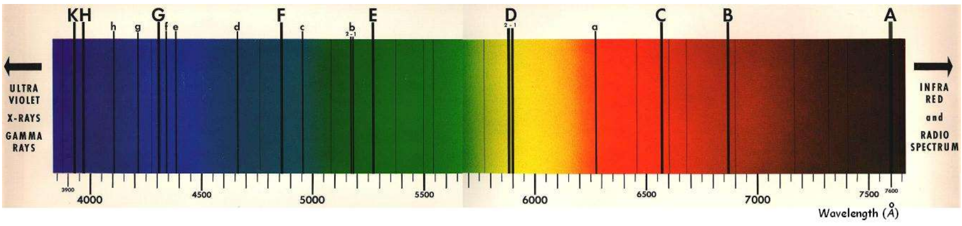


Plan and conduct a mission to deliver an exploration crew to Mersereau-2012A and, if possible, safely land them on it.

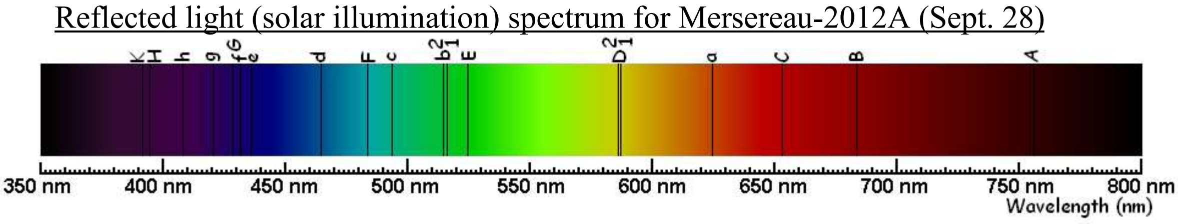
Appendix B

Data

Zero-velocity solar absorption spectrum



Reflected light (solar illumination) spectrum for Mersereau-2012A (Sept. 28)



Absorption Line	Element	Stationary Source wavelength (nm)	Mer-2012A wavelength (nm)
A	O_2	759.4	756.58
B	O_2	686.7	684.15
C	H	656.3	653.86
a	O_2	627.6	625.27
D1	Na	589.6	587.41
D2	Na	589.0	586.81
E	Fe	527.0	525.04
b1	Mg	518.4	516.47
b2	Mg	517.3	515.38
c	Fe	495.8	493.96
F	H	486.1	484.29
d	Fe	466.8	465.06
e	Fe	438.4	436.77
f	H	434.0	432.39
G	Fe, C	430.8	429.20
g	Ca	422.7	421.13
h	H	410.2	408.67
H	Ca	396.8	395.32
K	Ca	393.4	391.94

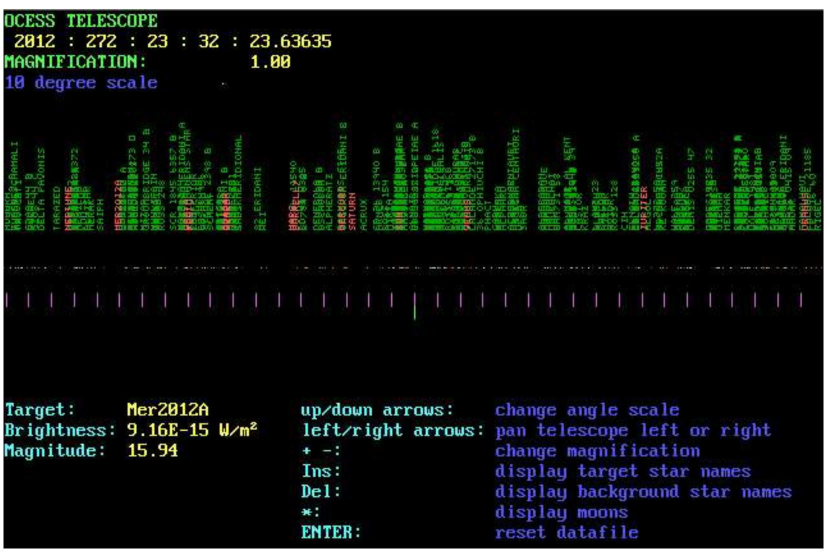
M-2012A blue shift data for Sept. 28

Brightness (Reflected Solar Light)

Sept. 28: Apparent Magnitude 15.94

Oct. 5: Apparent Magnitude 15.94

Angular motion from Sept. 28, 2012 to Oct. 5, 2010



Mersereau-2012A relative to star 1343 (OCESS deep-field star catalogue)

Sept. 28, 2012:
1746.2 arc seconds R

Oct. 5, 2012:
1938.8 arc seconds R

Quaoar (a distant Kuiper-belt object) relative to star 1242

Sept. 28, 2012:
61.5 arc seconds L

Oct. 5, 2012:
24.6 arc seconds R

Parallax software and weekly telescope observation data downloads are available on www.spacesim.org

Reference Websites

http://www.harmsy.freeuk.com/fraunhofer.html

http://en.wikipedia.org/wiki/Stellar_parallax

http://csep10.phys.utk.edu/astr162/lect/stars/magnitudes.html

http://en.wikipedia.org/wiki/Magnitude_(astronomy)
(note, solar visual brightness at earth is 1366 W/m^2)

http://en.wikipedia.org/wiki/Albedo

http://en.wikipedia.org/wiki/Effective_temperature
(equation for light power absorbed by a planet that could be modified to calculate reflected power)

http://www.school-for-champions.com/science/light_doppler_equations.htm

http://en.wikipedia.org/wiki/Blueshift

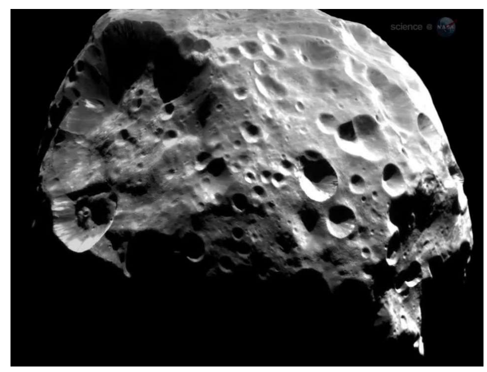
2) 2015 mission to Hyperion

OCESS Mission 2015

This is a mission to study some of Saturn's moons, particularly Hyperion as well as Iapetus and Phoebe. All three moons have significant quantities of dark organic matter, principally hydrocarbons (aliphatic and aromatic hydrocarbons (including polycyclic aromatic hydrocarbons (PAH)) http://en.wikipedia.org/wiki/Hydrocarbon). This mission will undertake a thorough analysis of the structure and composition of Hyperion as well as the composition of the other two moons to better understand the origin of the three moons and the material from which they are composed.

see youtube video: Xw8R8_1zB_A
http://www.nasa.gov/centers/ames/news/features/2009/identify_saturn_moon_surfaces.html
http://saturn.jpl.nasa.gov/science/moons/hyperion/
http://saturn.jpl.nasa.gov/science/moons/phoebe/
http://saturn.jpl.nasa.gov/science/moons/iapetus/

Phoebe
Thought to be a captured trans-neptunian object. For example, it has a highly inclined, retrograde orbit around Saturn. (http://en.wikipedia.org/wiki/Trans-Neptunian_object)
Phoebe's dark, reddish colour (albedo is only 6%) suggest that the surface is covered in organic matter. This was confirmed by reflectance spectroscopy.
Phoebe is of interest because trans-neptunian objects are thought to be primordial to the solar system. Their composition is thought to represent the material (organic and inorganic) that was native to the nebula from which the solar system formed.


http://www.nasa.gov/multimedia/imagegallery/image_feature_565.html

Iapetus
Iapetus is in a tidally locked rotation so that the same hemisphere faces Saturn at all times and, thus, the same hemisphere faces forward into the direction of its orbit. The forward face is covered in a dark material that is quite similar in its composition (according to reflectance spectroscopy) to the material on the surface of Phoebe.


http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA11690

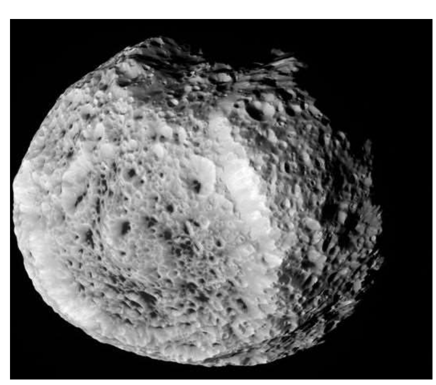
This suggests that Phoebe is ejecting organic material into a "phoebe ring" and that Iapetus is sweeping this material up as it moves through this ring in its orbit.

The light side of Iapetus also has dark organic material. This material has a different reflectance spectroscopic curve than the Phoebe material. Thus, this trailing hemisphere material may be native to the bulk material of which Iapetus is made.

Iapetus has a much lower density than that of Phoebe (1.08 vs 1.63). The conclusion is that Iapetus is composed mostly of water.

Iapetus was the destination of the 2009 OCESS mission, but this mission was plagued by technical problems and did not achieve many of its science objectives.

Hyperion
This is the primary mission destination.
Hyperion is slightly larger than Phoebe, but has a much lower density (approx. 0.5). Its mass is too small for it to have gravitationally contracted into a sphere. Its low density implies that it is composed mostly of water ice and that it must have considerable void spaces within it, though whether this is in the form of small pores or large void spaces is not known.


http://www.nasa.gov/mission_pages/cassini/whycassini/cassini20110826.html

Hyperion's orbital distance is very close to that of Titan's. Hyperion's chaotic rotation is possibly a result of periodic close encounters with the much larger Titan.

Like Iapetus, Hyperion has a significant amount of dark material on its surface. This dark material is quite similar, in respect to its reflectance spectroscopy, to that found on the trailing hemisphere (light hemisphere) of Iapetus. This material is concentrated mostly at the bottom of the craters.

Mission Goals

1) a) Sample the dark organic material on Hyperion, Iapetus, and Phoebe.
   - i) sample using towed sampling device while hovering over the surface.
   - ii) analyse material using mass spectrometry and chemical analysis (chromatography).

   b) Is the Hyperion and trailing-side Iapetus material part of the water ice from which these two moons are made or something that was brought in by impact bodies or swept up in orbit?
   - i) sample Hyperion material below the surface to look for organic material
   - ii) compare composition of subsurface organic matter (if any) to material at the surface
   - iii) look at surface material for evidence of how solar and cosmic radiation has affected it.

2) a) Why is the surface of Hyperion so strongly charged?
   - i) map the charge strength over the surface using a towed probe.
   - ii) does the charge strength correlate to exposure to solar and cosmic radiation and to Saturn's magnetic field?
   - iii) is the charge strength static or does it change with time?
   - iv) is the charge strength correlated to surface composition?

   b) How much of a danger does the static charge pose to spacecraft and surface exploration?
   c) Is it possible to discharge the surface enough to make surface exploration safe?

3) Is there any internal structure to Hyperion?
   - i) radar tomography using radar beams from AYSE to habitat while in opposite orbits.
   - ii) high frequency seismic tomography using probes landed on the surface.

4) Origin of Hyperion:
- is it similar in composition to comets such as C 103P Hartley?
  - i) capture ejecta from probe impact during high-speed flyby during transfer orbit.
- did it originally form as a single object or is it composed of a number of smaller bodies that have more recently coalesced into a single body?
  - i) analyse results for goal #3
  - ii) map composition w.r.t. organic material, isotope ratios and try to correlate to surface geographic features to see if there is any indication that there are distinct regions of the moon that may have formed separately from the others.

5) Determine if Hyperion could be a viable, low-gravity source of water and other resources for long-term exploration of the Saturn system.

APPENDIX C: SAMPLE PROCEDURE DOCUMENTS FOR 2015 MISSION

1) Master mission timeline

Notes	Procedure	Beta	Alpha	
	1) Launch from OCESS and dock with AYSE (ref: **Launch to Earth Orbit Procedures** document) Launch opportunities: 1657:42 hrs & 1826:21 hrs	44:xxxx	1600 to 2130	Friday
	Saturn transfer orbit (ref: **Saturn Transfer Orbit** document) - C 103P Hartley sampling - Course correction - EVA for comet sample retrieval - Phoebe periapsis (record visual obs) - Saturn periapsis (record visual obs) - Hyperion orbit	 48:0935 50:0100 50:0400 51:0948 51:1309 52:2000	0935 1100 1150 1155 1230 1240 1330	Tuesday
	1) Assess stability of 4000 km orbit (drift over lunch period) 2) Lunch		 1330	
	1) Hyperion surface mapping (box orbit - 4000 km periapsis) - activate camera - maintain ccw prog orientation except at turning points 2) Preparation of C 103P H samples for analysis	52:2100	1430	
	1) Electrostatic risk assessment - undock from AYSE - gradual descent to 5 km - monitor electric field strength and discharge frequency - assess discharge consequences to spacecraft systems		1500	
	1a) Assess electric field strength 1b) Map surface elevations 1c) Map surface composition - establish a circular orbit at 10 km above highest elevation (may use higher orbit, but not so high that Saturn gravity affects circularity) - complete at least one orbit - deploy towed EM probe - activate optical reflectance scaner - initiate recording program for field, alt., & optical scanner - record radar altitude of key features on surface map 2) Preparation of C 103P H samples for analysis (ref. planetary sample analysis procs.)		1600	
	1) Radar tomography procedure - dock with AYSE - proceed to altitude of 50,000 km - establish 1000 m/s orbit w/ 100 km periapsis - undock and move to opposite corner of box orbit - establish 1000 m/s orbit w/ 100 km periapsis opposite to AYSE - initiate AYSE radar pulse and HAB recording at 300 km alt. - dock with AYSE and repeat at different orbit angle 2) Analysis of C 103P H samples (ref. planetary sample analysis procs.)		1700 to 1900	
	1) Supper		1900	
	1) Analysis of mapping and tomographic data. 2) Analysis of C 103P H samples 3) Determine location for seismic recording and blast probes		2000	
	1) Deploy seismic recording probes 2) Place AYSE and Hab in stable orbits.		2100 to 2200	
	Overnight activities: 1) Sample analysis 2) Mapping analysis - esp. collection sites for next day 3) Stellar parallax measurements 4) Onboard fire drill 5) Determine mass and volume of Hyperion; calculate density 6) Record output from seismic probes		48:2200 to 49:0800	Wednesday

Appendix C

Notes	Procedures	Beta	Alpha	
	1) Breakfast 2) Network check and overview of schedule with MC		0800	Wednesday
	1) Evaluation of discharge abatement procedures if needed a) generate charge imbalance with engines for approach/landing. - will not help with EVAs - unbalance the charge flow from engines at low thrust - return to balanced exhaust when sufficient static charge - descend to surface and evaluate discharge frequency b) create a discharge channel with engine exhaust - measure field strength at low alt. - fire engines at surface - re-measure field strength (consider procs. to avoid discharges through exhaust plume) 2) Evaluation: fuel consumption and return transfer orbit reserves.		0900	
	1) Seismic analysis of Hyperion substructures - launch explosive probes at previously determined location(s) - analyse recordings uploaded from seismic recorder probes		1000	
	1) Assess methods for surface and subsurface sampling a) specific locations in light of mapping results b) suitably safe methods in light of previous analysis i) deploy towed sampling probe while hovering (best method for sampling organic material in craters) ii) deploy towed probe with coring device while in hover (would probably lose surface material) iii) use remote coring device while on surface without EVA iv) surface exploration by EVA v) explosive excavation of fresh, unweathered material (use with any of the above methods) We want to consider how many different localities we need to sample to address the second question in objective 4 in the mission briefing statement. 2) MC simulates flight procedures for sampling methods		1100	
	1) Lunch 2) MC simulates flight procedures for sampling methods		1200	
	1) Carry out surface sampling or organic matter in craters		1300	
	1) Carry out surface & subsurface sampling: use agreed method(s) - upload procedures from MC - carry out procedures		1430 to 1800	
	1) Supper		1800	
	1) Continued surface/subsurface sampling. 2) Sample analysis.		1900 to 2200	
	Overnight activities: 1) Sample analysis 2) Mapping analysis - esp. collection sites for next day 3) Stellar parallax measurements		2200 to 0800	Thursday

Appendix C

Notes	Procedures	Beta	Alpha	
	1) Breakfast 2) Network check and overview of schedule with MC		0800	Thursday
	1) Continue surface/subsurface sampling 2) Continue sample analysis		0900 to 1200	
	1) Lunch		1200	
	1) Continue surface/subsurface sampling 2) Continue sample analysis		1300 to 1800	
	1) Supper 2) Evaluation of progress towards mission goals to date		1800	
	Evening activities dependent on outcome of evaluation			
	Overnight activities: 1) Sample analysis		2200 to 0800	Friday

Notes	Procedures	Beta	Alpha	
	1) Breakfast 2) Network check and overview of schedule with MC 3) Evaluation of progress towards mission goals to date		0800	Friday
	Choices for further investigations: a) continued exploration and sampling on Hyperion b) initiate transfer orbits to i) Enceladus, ii) Iapetus, iii) Phoebe - surface sampling of Enceladus to look for similarity in composition to Hyperion (ref. similar origin of these moons) - surface sampling of Iapetus to look for similarity in composition to Hyperion (ref. similar origin of these moons) - sample leading and trailing hemisphere dark organic matter - surface sampling of Phoebe to look for similarity in composition to Hyperion and esp. dark organic matter for comparison to Iapetus material - attempt to measure presence of organic matter in Phoebe ring and determine if Phoebe organic matter is being concentrated by Saturn's magnetic field and if it is present in significant amounts anywhere along the orbital path of Iapetus			
	1) Develop mission timeline with MC.		0900	
	1) Carry out mission plan 2) MC develops and tests Earth return transfer orbit - factor in possible need for second attempt at C 103P H sample			
	Overnight activities: 1) Sample analysis 2) Go over transfer orbit plan with pilot and commander 3) Start spacecraft inspection for issues relating to planetary protection on return to earth. - discuss any problems with MC and develop a report for the planetary protection officer			Saturday

Notes	Procedures	Beta	Alpha	
	1) Breakfast 2) Network check and overview of schedule with MC 3) Evaluation of progress towards mission goals to date 4) Brief crew on transfer orbit procedures and timeline 5) Discuss report to planetary protection officer and remedial actions necessary		0700	Saturday
	1) Initiate transfer orbit procedures 2) Initiate planetary protection actions		0830	
	1) Earth orbit insertion and landing at OCESS		1230	

2) List of Potential Simulator Events

1) Mechanical failure on launch.
    - engine failure
    - main bus short circuit
        - vibration causes something conductive to touch the bus.
        - switch to an standby power bus w/ lower max current
            - would take them longer to reach orbit
            - might have to circularize at a lower orbit then transfer to intended orbit
    - coolant system malfunction
    - electrical bus voltage regulator malfunction
    - NAV computer malfunction
    - NAV component malfunction (e.g. INS, Radar)
    - high wind/turbulence

2) Asteroids placed in path during transit of asteroid belt
    - need training on implementation using sim software.

3) Communications loss while in Saturn system:
    - use ULF back-up communications in code
    - could have them use Cassini as a communications relay
        - they would have to lock on to Cassini and track it
        - would have to work out a doppler correction
    - prepare phone numbers to call for MC to contact Cassini mission control for assistance (several alumni are prepared to act in this capacity)

4) Cave-in while exploring Hyperion caves.
    - implement a seismic event
    - astronauts would have to go to/find the other exit of the cave system or try enlarging the exit.
        - implement by altering the hyperion data in the StarsR file to narrow the gap
        - we would force a restart of the orbit software to reload the starsR file
        - this could be associated with the conjunction with another of the moons
            - if they need to use a communications relay while in the cave, then this could be associated with a partial or total comm failure
        - ULF text communications might be able to pass through ice?

5) Other mechanical failures (in addition to launch malfunction list)...
    - NAV computer failure or some other control computer failure
        - replace/repair circuit components in eng. closet
    - Coolant leak
    - CO_2 scrubber replacement
    - EVA tank pressurization equipment failure
    - circuit breaker malfunction
    - simulators could alter components in the closet during the mission using "secret hatch"

6) Solar flare event either on outbound or inbound transfer orbit
    - not much danger all the way out at Saturn and could hide behind Hyperion
    - event on transfer orbit could necessitate
        - evacuation to bunks
        - shut-down of vulnerable equipment (radar, comms)
    - implementation would require sufficient time in the alpha schedule

7) Small asteroid impact.
- can happen at any time and without any warning
- damage mechanical/electrical systems
- damage sensors on hab exterior: radar, communications, engines etc.
- loss of atmospheric pressure events

8) Electrical discharge (should happen repeatedly while above Hyperion's surface)
- should not cause damage,
    - but we could have them pop virtual circuit breakers and flicker the lights
- could cause circuitry malfunctions that need to be repaired
    - maybe the old standby of requiring EVA to the exterior access hatch
        - this would be nerve-wracking if still in range of static discharges
        - astronauts or MC may decide to move to a higher orbit first

9) Moving objects on orbit software during one or more night shifts when there are only one or two astronauts awake and performing maintenance and science duties.
This ought to be significantly un-nerving.
Astronauts and MC would have to decide whether to wake the other astronauts or not.
We would have to be prepared for the mission team to suspend EVAs, so this might be better to do later in the cave exploration rather than earlier.
Could hang stationary (perhaps shifting of structures in cave causing ghost radar images or interference of radar pulses echoing within the confined space) or have them drift downwards (falling stalactites).
- could have stalactite impacts on hab.

10) Malfunctions in science equipment.
- e.g. plugged inlet tube for mass spectrometer
  exterior gas analyser inlets
  exterior radar transceiver

11) Interior fire.
- need to complete development of simulated fire
- practice fire fighting should occur prior to mission so that astronauts are
    - familiar with the effect
    - familiar with fire fighting techniques

12) Warning sensor errors (fire, gas concentrations, door circuits).
This will cause uncertainty in the astronauts as to the reliability of their equipment.

13) Navigation computer error with no warning indication.
e.g.: have the NAV mode switch to manual mode with no change in the indicator while under power.
this would put them off course.
astronauts and MC would have to:
1) recognise the problem
2) implement corrective action
3) put the spacecraft back on the flight profile, or
   devise a new flight profile and set the spacecraft to that
4) repair the NAV computer

3) Launch to Earth Orbit Procedures (first item in the master mission timeline)

Step	Flight	Engineer (monitored by GUIDO)	FIDO	EECOM & EECOMMC
1	i) Start FLIGHT.EXE ii) select OCESS as centre iii) confirm time sync	i) start engSThab.exe - press enter for cold start - press enter for local path - press enter to not restore state - enter assigned HAB fuel - enter assigned AYSE fuel - press enter AFTER flight.exe starts ii) confirm time sync	i) start MIRROR.EXE ii) confirm time sync	i) start EECOM.EXE ii) confirm time sync
2		a) Complete **Cold-start Checklist**		b) Complete supplies checklists
3		a) activate INS, GNC, LOS, RADAR b) activate RSCP		c) Doors test d) Static pressure tests: ~ 20% over pressure & hold 5 min ~ non-adjacent rooms simultaneous e) Verify biomed readings f) Test filters and scrubbers g) Note int. & ext. radiation levels h) ensure all air bottles are filled
4		a) activate RAD shield A @ 5% c) activate RAD shield B e) set RAD shields to 0% f) deactivate RAD shields		b) verify int rad level drops d) verify int rad level drops
5	Confirm NAV data displays function			
6	Select NAV mode “deprt ref”			
7	Confirm NAV stays in this mode			
8	a) set targ=AYSE b) set ref=earth c) orientation display to ΘPch d) display reads reference (“R”)			

9	a) confirm HAB fuel approx. 25000 d) confirm RCSP @ or apprch. 100	b) confirm HAB fuel @ 25000	c) confirm HAB fuel @ 25000 e) confirm RSCP @ or apprch. 100	
10	****** @ ΘHrt = 45º (T+600s) ******			a) verify atmospheric conditions within limits for launch
11			a) set telemetry to OFF b) advance to @ ΘHrt = 18º note time c) advance to @ ΘHrt = 14.5º note time d) set telemetry to ON e) DISPLAY software: set event timer to time in step b) (F11) set MST to time in step c) (F12)	
12		a) activate engines (close f to m) b) activate reaction gas injectors (1 & 2) c) confirm no malfunctions		
13		a) deactivate reaction gas injectors		
14		a) confirm FC operational b) confirm BATT1 operational		
15		Isolate BUS2 & BUS3 (open o,q,p)		
16		Confirm BATT2 operational		
17		Confirm positive air intake		
18		a) confirm engine coolant set to “B” b) confirm reactor coolant set to “B”		
19		Confirm reactor connected to BUS1 (z)		
20		a) confirm radiators 1&2 retracted b) confirm radiator 3 extended c) confirm radiator 3 on loop 1 d) confirm radiator 4&5 on loop 2 e) confirm Hi & Low press pumps ON for loops 1 & 2 f) confirm loops 1 & 2 stabilizing < 20		

21		a) BATT1 to OFF b) confirm FC @ ~69A c) confirm BUS1 @ ~130A; 10000V d) confirm HAB fuel flow @ 34 kg/hr fuel supply should drop 1 kg/2 min		
22	b) Set engines to 5 %	a) confirm engine gas injectors OFF		
23			a) load flight track "launch" b) DISPLAY software: set "TARGET" to ABORT landing site in northwest Africa c) confirm AYSE alt ~560 km	
24		Confirm: a) engine temps rising b) BUS1 @ ~24400A, ~9995V fuel flow @ ~910 kg/hr fuel drops 1 kg/4s		
25	Engines to 0% when engine temps >10			
26	@ ΘHrt = 20º (T-82s)	***** a) set engine gas injectors to ON *****		b) confirm crew at launch stations
27	@ ΘHrt = 19º (T-67s)	** a) Radiator 3 to ISOL and retract **		
28	@ ΘHrt = 18º (T-52s) a) ***Confirm ready for lift off***	b) ***Confirm ready for lift off***	c) ***Confirm ready for lift off***	d) ***Confirm ready for lift off***
29	@ ΘHrt = 17º (T-37s) a) engines to 65%	b) confirm engines @ 65% d) confirm: BUS1 @ 314726A, 9921V fuel flow @ 11358 kg/hr e) note coolant, reactor, engine temps record peak temps when reached	c) confirm engines @ 65%	

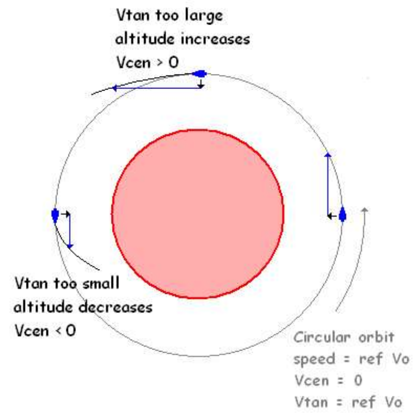
30	@ ΘHrt = 14.5° (T+0) b) confirm lift off	a) ignite SRBs	c) confirm lift off d) commence monitoring flight track report major deviations from track	
31				a) confirm biomed readings nominal
32	a) select NAV mode “manual” c) select target = “earth”		b) confirm NAV mode “manual” d) confirm target = “earth”	
33	@ Qmax (~27.2 5.2km, T+16s) a) engines to 90%		b) confirm engines @ 90%	c) confirm ambient pressure drop
34	@ alt = 25 km (T+41s) a) initiate 2°/s ccw roll c) engines to 50%		b) confirm ccw roll d) confirm engines @ 50%	
35	@ Q <0.005 (~90 km, T+76s) b) engines to 60%	a) extend radiator 3 radiator 3 to loop 1 radiators 4&5 to loop 2 d) confirm temps < critical	c) confirm engines @ 60%	e) confirm ambient pressure = 0
36	@ ΘPch = 90° (~115km, T+88s) a) select NAV mode “ccw prg”	c) confirm temps < critical	b) confirm NAV mode “ccw prg”	
37	@ SRB OFF (~178 km, T+120s) b) engines to 90%	a) extend radiators 1&2 radiator 1 to loop 1 radiator 2 to loop 2 d) confirm temps < critical	c) confirm engines @ 90%	
38				confirm compartment pressures stable
39				monitor CO2 and H2O levels scrub when levels generate a warning do NOT scrub below safe levels

40	a) monitor apoapsis		b) monitor apoapsis call out apoapsis @ 500 call out apoapsis @ 10km intervals	
41	@ apoapsis = 560km a) MECO	b) confirm MECO d) confirm temps dropping	c) confirm MECO	
42	a) monitor altitude		b) monitor altitude call out altitude @ 500km call out altitude @ 10km intervals	
43	@ altitude = 560 km a) engines to 100%	c) confirm: BUS1 @ 482138A 9879V fuel flow = 17386 kg/hr	b) confirm engines to 100%	
44	@ Vtan = ref Vo a) MECO	b) confirm MECO	c) confirm MECO d) confirm alt ~565 km	
45	Circularize orbit a) NAV mode to "app targ" c) ±10% engines to zero out Vcen d) NAV mode to "ccw prg" f) ±10% engines to set Vtan=ref Vo g) evaluate Vcen&Vtan repeat steps as needed		Monitor apoapsis, periapsis, alt b) confirm NAV mode "app targ" e) confirm NAV mode "ccw prg" h) evaluate Vcen&Vtan	
46	a) set NAV mode = "ccw prg" b) select target = "AYSE"		c) confirm HAB is behind AYSE and distance to AYSE is <50 km & stable	
47				Confirm with EECOMMC that interior radiation levels are safe. Evaluate need for RAD shields.

48	*** Complete AYSE docking checklist ***			
49		Extend RAD6 Set RAD6 to loop 2 Set all HAB systems to loop 2 only		
50		Link BUS1 and AYSE BUS (F1&F2)		
51		Evaluate AYSE reactor status.		
52		Link BUS1 & BUS2 & BUS3		
53		a) disconnect FC b) shut down FC (7) c) confirm switches f to m and s OPEN		
54		Confirm AYSE reactor is feeding power to BUS1: a) open switch F1 and confirm: HAB reactor current increases AYSE reactor current decreases b) close switch F1 and confirm: HAB reactor current decreases AYSE reactor current increases		
55		a) disconnect HAB reactor from BUS1 b) shut down HAB reactor fuel pumps c) monitor HAB reactor temp d) when reactor temp < 30 open switches d & e		
56		a) open switch t b) confirm AYSE fuel flow < 1 kg/h c) close switch t		
57				Confirm with EECOMMC that interior radiation levels are safe. Evaluate need for RAD shields.
58		a) set F6,F7,F8,F9,F10 to ON b) confirm radiators 7&8 on loop3		

APPENDIX D: SAMPLE TRAINING DOCUMENTS
1) Sample Primary Procedure Training Document

Introduction to Orbital Maneuvering
(Intended for guided training with an experienced member)
Print and read the orbit controls document.
For additional explanations, read pages 5, 6, 11, 12, & 13 in the OCESS procedures manual.
All software is available from the spacesim website.



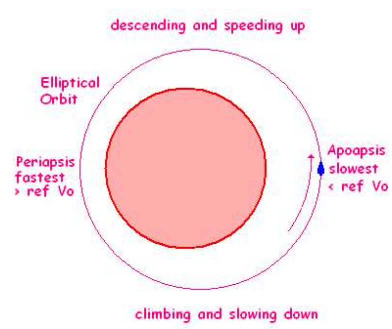
Training Assignment 1A: circularize orbit

a) start ORBIT5Tm.exe
press ***ENTER***
press ***X***
press R to load the file **TEST1A**

b) press ***p*** to display target velocities
c) set earth as **center**, **target**, **ref**
d) check apoapsis and periapsis
if the periapsis is less than 100 km, the orbit will enter the atmosphere, and you will crash

Circularize the Orbit
e) select NAVmode app targ; wait for spacecraft to reorient
f) use main engines at high negative thrust to change Vcen to zero (it will drift)
in a circular orbit - the in-and-out velocity (Vcen) should be zero
- Vtan will equal ref Vo
- the apoapsis and periapsis should be zero
check apoapsis and periapsis to see if orbit is more circular (press **o** to display orbit path).
g) select NAVmode ccw prog; wait for spacecraft to reorient
h) use main engines at high thrust to change Vtan to match ref Vo (it will drift)
In a circular orbit, the spacecraft has a sideways velocity (Vtan) that is just fast enough to counteract the downward acceleration due to gravity at that orbital altitude.
check apoapsis and periapsis to see if orbit is more circular (press **o** to display orbit path).
i) repeat steps e & f using lower thrust settings
j) repeat steps g & h using lower thrust settings
k) staying in NAVmode ccw prog, use RCS thrusters to complete the process of setting Vcen and Vtan
l) check apoapsis and periapsis to see if orbit is more circular (press **o** to display orbit path).

Note: if Vtan < ref Vo or Vcen < 0 (you are dropping)
- you are **not** necessarily going to crash
- as the spacecraft falls, it speeds up like a car rolling down a hill
- as it speeds up, Vcen will get less negative
- the speed will eventually get so high that Vcen will get positive



Training Assignment 1B: shift to a higher circular orbit

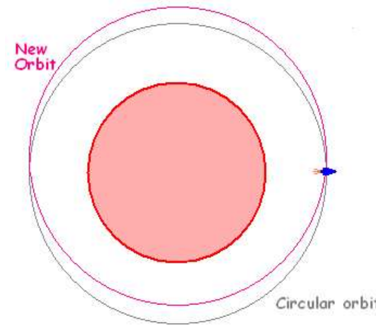
a) start ORBIT5Tm.exe
press ***ENTER***
press ***X***
press R to load the file **TEST1B**
b) press ***p*** to display target velocities
c) set earth as **center**, **target**, **ref**

Goal: investigate the effect of changing velocity on orbital altitude.
The ultimate goal of this activity is to rendevous with a target in a higher orbit: the AYSE drive unit. To do this, we will make use of the HAB engines to alter the orbit of the HAB.
HAB initial altitude : 500 km & circular (check the distance readout and press **o** to verify)
AYSE initial altitude: 2509 km & circular

Circular orbit means that apoapsis (high point) = periapsis (low point)

Orbit display (press **o**) shows you the path around the reference object that the HAB *will follow* ***if*** the engines are turned off. Periapsis and apoapsis values update continuously.

Appendix D



Trial 1) use engines to push HAB upwards

d) set NAVmode to deprt ref

e) set engines to +100%

f) monitor apoapsis, periapsis, Vcen, and Vtan

Q: does the apoapsis increase?

Q: does Vcen increase?

Q: what happens to Vtan?

Check the projected path displayed by pressing **o**.

Q: Where does the high point occur relative to the current location (which side of earth)?

Q: What is happening to the periapsis as the apoapsis increases?

Q: What happens to the periapsis before the apoapsis reaches 2509 km?

Q: Why is this an unsafe means of moving to a higher orbit (think engine failure)?

Restart

g) reload **TEST1B** (press **r**, type Test1b...)

h) check that NAVmode is in ccw prog (HAB is pointing in direction of motion)

i) set engines to +100% (the engines are pushing the HAB sideways relative to the earth)

j) monitor apoapsis, periapsis, Vcen, and Vtan

Q: does the apoapsis increase?

Q: does Vtan increase?

Q: what happens to Vcen?

Check the projected path by pressing **o**.

Q: Where does the high point occur relative to the current location?

Q: What is happening to the periapsis?

Q: What is the lowest point that the spacecraft will reach if the engines fail at any point?

k) continue to monitor apoapsis

shut off engines when apoapsis reaches 2509 km

if you overshoot use low negative engine thrust to bring apoapsis down to 2509 km

l) At this stage of the process, we just coast p to the apoapsis

press * to set time acceleration to 0.375 so that it does not take half an hour to get there.

m) monitor the progress of the HAB as it climbs up to apoapsis.

Q: what happens to Vcen and Vtan as the spacecraft climbs? what causes this?

Q: do the HAB and AYSE meet at the apoapsis?

Q: Which spacecraft reaches the apoapsis point of the HAB's orbit first?

Q: What would you have to have done differently (think timing) to make the two spacecraft meet?

Restart

n) press **r** to reload **TEST1B**

o) press * to set time acceleration to 0.375

Q: Are the HAB and AYSE orbiting at the same speed? If not, which is faster?

Q: If you wait until the right moment, would it be possible to repeat steps **h** to **m** so that the HAB and AYSE did meet?

p) Press **q** then **y** then **ENTER** to exit the software.

q) Start the program **TRANSORB.EXE**

r) Select **Earth** (3) as the current orbit

Enter 500 km as the starting altitude

Enter 2509 km as the ending altitude

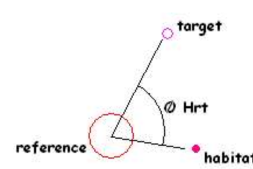
Enter 10 as the engine acceleration

Record the following output data:

delta-V (tells you how much you need to add to your Vtan)

engine burn time (tells you how long an engine burn at the entered engine accel.)

trail object by (tells you the Hrt angle you need to have relative to the target, AYSE in this case, in order to meet it at the apoapsis).



Hrt is the angle between you and the target object with the centre of the reference object as the vertex of the angle. This angle is displayed in the orbit software. If the reference and target are the same object, the **Hrt** is zero degrees.

s) press any key to return to the select current orbit option and enter **q** to quit.

t) Restart **ORBIT5Tm.EXE**

Repeat steps **a** to **c**.

u) Press * to accelerate time to 0.375

v) Monitor **Hrt**. It should be decreasing, indicating that you are catching up with AYSE

w)

x) Press / just before it reaches the angle given by **TRANSORB.EXE** to go back to the normal passage of time.

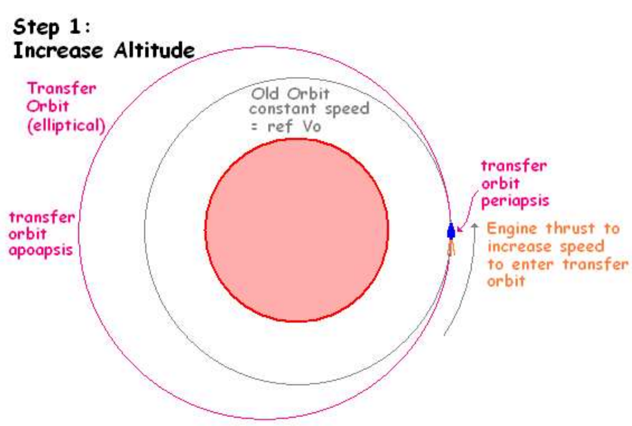
x) Add the delta-V given to you by **TRANSORB.EXE** to the displayed ref Vo speed.
This is your target Vtan.
Take the engine burn time given by **TRANSORB.EXE** and divide by 2
When you estimate that you are about that much time before the critical **Hrt** is reached, set the engines to generate 10 m/s^2 acceleration.

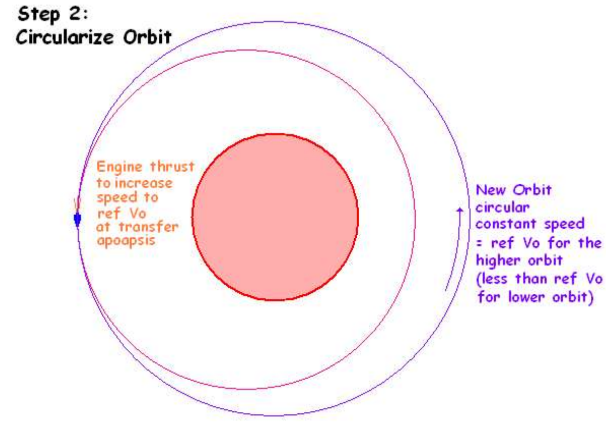
y) When your Vtan reaches the target Vtan, shut off the engines.
Since Vtan starts to decrease immediately, you cannot correct any over or undershoot of target Vtan.

z) Press ***** to accelerate time to 0.375 until just before apoapsis is reached.
At apoapsis: Vcen will be zero
the AYSE drive should be within a few kilometres
Vtan will be slower than ref Vo

aa) Ensure that you are still in NAVmode **ccw prog** then use engines to accelerate Vtan until it is equal to ref Vo.

ab) Set target to AYSE and monitor distance to target. It should be fairly constant.

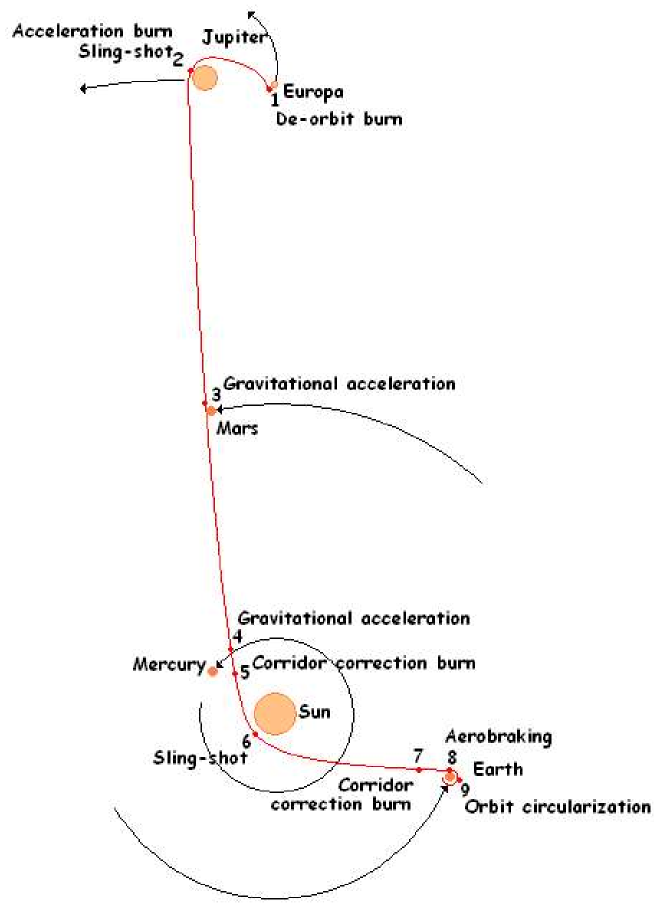




2) Sample Planning Training Document.

Low-Energy Return from Europa

176 days duration.
4 minutes total engine use time.



Whenever necessary, the radiation shield magnetic field generators should be set to 100%.

Start Orbit5S
Load file "Europa"
Start Orbit5SE
- hot start
- select correct network drive
  (this drive must be active)
- AYSE should be "in position"
- dock with AYSE and turn on all engines

1&2) Departure from Jupiter system

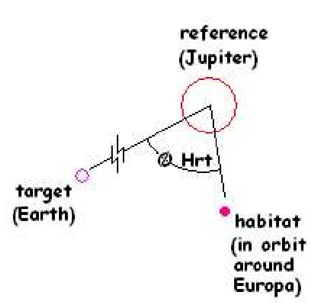
Rather than a direct departure away from Europa, we will perform a de-orbit burn while in Europa orbit to fall towards Jupiter. As the spacecraft approaches its periapsis of 10,000 km it will accelerate. At periapis the speed will be nearly 4 times faster than it was in orbit around Europa. At this point, the engines will be fired prograde to accelerate the spacecraft to 80,000 m/s. This method achieves a the same velocity as a direct departure with less than half the fuel used.

The critical parameters for this manoeuver are:
a) maximum speed after periapsis (more = more speed, but smaller direction change)
b) periapsis altitude (lower altitude = more speed and a larger direction change)
c) angle between target, reference, and spacecraft (affects the direction after periapsis)

Since it is hard to manage 3 variables, I will set two of them for you:
a) the maximum speed after periapsis (speed after the engine burn is over): 80,000 m/s

b) the periapsis altitude: 10,000 km

1) **De-orbit burn**
Set: target = Earth
ref = Jupiter
orientation = ccw retro



a) Correct ΘHrt.
The Jupiter sling-shot manoeuver results in about a 270° change in direction, so the ΘHrt that you need is around 90°. The correct angle must be determined by trial and error. A 0.1° change in angle can produce a difference of millions of kilometres in how close you get to the Earth at the end of the voyage.

Decide on a ΘHrt angle, record it, then try it out, running the process to step 7.

b) De-orbit burn duration.
The TRANSORB software can be used to calculate an approximate change in speed that your de-orbit engine burn must achieve.
Set: target = Jupiter
ref = Jupiter
Read off the distance to target.

<u>TRANSORB Input</u>

current orbit:	5 (Jupiter)
current altitude:	(distance to target read off from the ORBIT5S software)
ending altitude:	10,000 km
engine acceleration:	180 (not critical for this application)

<u>TRANSORB Output</u>

delta-V:	this is the amount by which your orbital speed must change.

The delta-V will be negative, since we are dropping down in altitude. This means that we must slow down in our orbit around Jupiter (while not crashing into Europa, around which we also are in orbit).

Post de-orbit burn speed = ref Vo + delta-V

We must use ref-Vo as our starting speed rather than V hab-ref, since, being in orbit around Europa, our V hab-ref is constantly changing as we go around Europa.

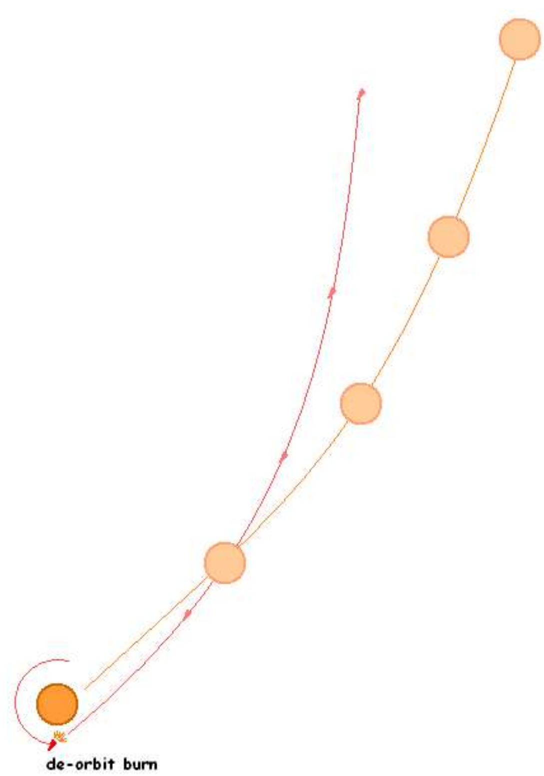
TRANSORB only gives an approximate delta-V. As we start to fall towards Jupiter, Europa will pull ahead of us. While we are still close to it, its gravity will tend to pull us forward, speeding us up and giving us too much speed, which will result in a periapsis above Jupiter that is too high. To compensate for this, you will need to slow down more than the TRANSORB delta-V suggests.

Save you state to a file before the de-orbit burn so that you can easily retry the manoeuver until you get the correct delta-V.

c) <u>Initiate de-orbit burn</u>
Make certain that your orientation is still ccw retro.

Once you have a delta-V that you want to try out, re-select Earth as your target until the spacecraft is at the ΘHrt that you are going to try.

At this moment, select Jupiter as the target so that you can monitor your speed around Jupiter. Immediately select full thrust (you only have a few seconds to start this before you are no longer at the correct ΘHrt)



Unless you are directly between Europa and Jupiter or directly opposite Jupiter, your Vcen will not be zero. This will affect your periapsis speed, altitude, and position. Even then, Vcen will be small, but not zero as Europa's orbit is not circular.

To compensate for this during you de-orbit burn select manual orientation, rotate slightly to one side or another until Vcen is approximately zero.

When the desired de-orbit speed is reached, shut off the engines.

As soon as the de-orbit burn is complete, Vcen will start to go negative as the spacecraft falls towards Jupiter. This is normal.

Set time acceleration to 0.375
When the spacecraft is a few thousand kilometres from Europa, set time acceleration to 10.000
When the spacecraft is close to Jupiter, set time acceleration to 2.000. Continue to reduce time acceleration as you get closer to periapsis so that: 1) you don't overshoot and, 2) don't alter the periapsis with to overly-large time steps.

d) Judging your de-orbit success
When close enough to Jupiter, press ‘o’ to project your orbit.
i) If periapsis projection is within 10 km of 10,000 km, continue to coast towards the periapsis.
ii) If periapsis is within 100 km of 10,000 km, you can try to adjust by applying engine thrust towards or away from the planet.
iii) If your periapsis projection is more than 100 km away from 10,000 km, reload your saved state and try another delta-V (slow down more if your projected periapsis is to high, slow down less if it is too low).

2) **Jupiter Sling-shot and Acceleration Burn**
Set: orientation = ccw prog
target = Jupiter
ref = Jupiter

Exactly at periapsis (Vcen = 0) apply full thrust.
When V hab-ref = 80,000 m/s, shut down engines. Try to hit 80,000 m/s to within 10 m/s.

As you climb away from Jupiter, your V hab-ref will decrease. This is because Jupiter’s gravity will continually slow you down. This is normal, but it also means that you cannot adjust your V hab-ref if you overshoot or undershoot it. When you get farther from Jupiter and closer to the Sun, the Sun’s gravity will start to speed you up again.

Set time acceleration to 0.375
When 1,000,000 km from Jupiter, set time acceleration to 2.000
When 2,000,000 km from Jupiter, set time acceleration to 60.000

Set: target = Sun
ref = Sun
orientation = deprt ref

This orientation will keep the heat/radiation shield between the crew cabin and the Sun for extra protection from solar radiation.

3) **Close Approach to Mars**
No action is required for this.
Mars’ gravity will accelerate the spacecraft to a greater speed.
We can zero out the mass for Mars in the StarsR initialization file to see how much Mars actually alters the spacecraft’s trajectory.

4) **Close Approach to Mercury**
No action is required for this.
Mercury’s gravity will bend the trajectory away from the Sun.
We can zero out the mass for Mercury in the StarsR initialization file to see how much Mercury actually alters the spacecraft’s trajectory.

5) **Corridor correction Burn**: 56 million km from the Sun

A speed correction burn ***may*** be required to get the spacecraft into the correct corridor around the Sun for the solar sling-shot manoeuver.

Save your state to a file at this point, so that you can go back and try other burn times if needed.

During this manoeuver the spacecraft orientation must be changed. The heat/radiation shield will no longer offer protection from solar radiation (although the spacecraft hull and magnetic shields will still work). For this reason, this engine burn must be as short as possible (10 s usually is long enough) and occur reasonably far from the Sun.

Set: target = Sun
ref = Sun

Speeding up: set orientation to **pro Vtrg** and apply full thrust.
Slowing down: set orientation to **retr Vtrg** and apply full thrust.

If you must change the speed by more than 2000 m/s, go back to step 1 and try a different ΘHrt.
You will know what changes to your speed are needed at this point after you complete step 7.

6) **Sling-shot Around Sun**
Set orientation to **deprt ref** and keep magnetic radiation shield at maximum.
No other action is required or possible at this point.

7) **Course Correction Burn**
Set: target = Earth
ref = Earth

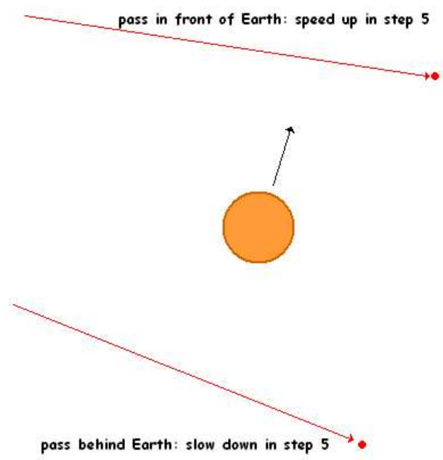
When you are within 500,000 km of earth, press ‘o’ to project your orbit.

Possible Situations:
a) you never get closer than 5 million km to Earth:
- go back to step 1 and try a different ΘHrt.

b) closer than 5 million km to Earth, but farther than 5000 km:
- go back to step 5 and adjust speed.

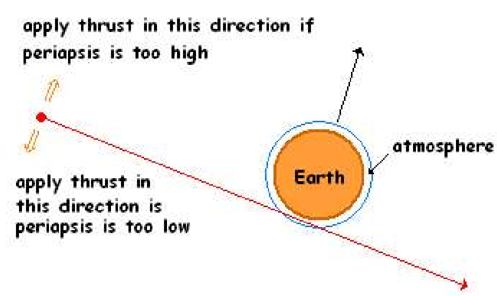
Slow down if you went behind the Earth (you need to give the sun more time to alter your direction).

Speed up if you crossed in front of the Earth (you need to give the sun less time to alter your direction).



c) Your projected periapsis is less than 5000 km:
- use engine thrust perpendicular to your velocity to alter your periapsis.

Set: target = Earth
ref = Earth
orientation = manual



Save your state to a file at this point.

Your goal is to have a periapsis of between 30 and 50 km above the earth.
- If you are too high, you will not slow down enough.
- If you are too low, you will slow down too much, will not be able to enter orbit, and crash.

The exact periapsis altitude depends on your speed. The faster you are going, the lower you need to go to have enough atmosphere to slow you down.

8) **Aerobraking**
Set: target = Earth
ref = Earth
orientation = retr Vtrg
anti gravity = max

retr Vtrg orientation keeps the heat shield forward of the rest of the spacecraft. If any other orientation is used, the spacecraft will burn up.

Do not fire engines while aerobraking as they will be damaged.

Target V hab-ref after aerobraking: between 8000 m/s and 12000 m/s.
If your speed is not within this range, reload you last saved state, go back to step 7, and try a different periapsis. A lower periapsis will cause a greater reduction in speed.

9) **Circularize Orbit**:
Follow steps in Initial Training Assignment 1A.

10) **Undock from AYSE drive and Land**
Follow procedure from OCESS procedures manual or Landing Training Document.

Appendix D

3) Sample EEP Training Document

<u>Rockets EEP Presentation</u>

Lead questions: What is a satellite? *Anything that orbits another object.*
Which were the first three countries to put satellites into outer space?
In order (Russia, USA, Canada).
Which was the first country to put a satellite into space for a useful purpose?
Canada launched Alouette-1 to study the upper surface of the ionosphere, a layer of the atmosphere off of which radio signals bounce.
There are three parts to any space mission: what are they? *launch, orbit, landing*

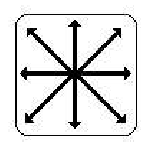
<u>Launch</u>

1) How do we get space craft into outer space?
Rocket engines.

2) What is a rocket engine?
How is it different from a jet engine?
Rocket and jet engines both burn fuel to produce a force (or thrust) to push the craft forward.

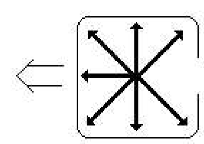
Burning fuel takes not just fuel, but... oxygen (and heat)
Jet engines suck in oxygen from the air.
In space, there is no air. So, rocket engines have to carry not only fuel, but oxygen as well.

3) How do rocket engines work?
They work just like a balloon.
When a balloon is blown up, the air pushes on all sides. Since the pressure on the inner surface is the same in all directions, there is no net force on the balloon and it stays put.



When the back of the balloon is opened, there is no surface for the air to push against and cancel out the pressure on the front surface. This front pressure pushes the balloon forward.

Demonstrate with the balloon on the straw and string.



In a balloon, as the air runs out, the pressure drops, and the pushing force decreases.
Rocket engines (and jet engines) burn fuel to maintain the pressure (until the fuel runs out).

4a) If you look at all the different rockets we have modeled, they all have the same sort of shape.
Show them the Saturn V (the launch vehicle of the Apollo moon rocket), the small hobby rockets (which look just like the Canadian Black Brant rocket used to study the ionosphere), and most of the parts of the shuttle launch vehicle).
They all have a long, cylindrical shape with a pointed nose.

b) Why do they have this shape; do they need it in space?
No, in space there is no air to resist the movement of spacecraft, they can have any shape at all.
They have this shape to help them push through the atmosphere when they launch.

c) Does the shuttle use its wings to launch?
No, it only uses them to glide to a landing after it gets back down into the atmosphere.
The shuttle is unique in that it returns to earth to be reused.

5) **Show them the Saturn V and the shuttle model.**
The Saturn V has several stages that fall off in sequence.
The shuttle has its main engines, fuel tank, and booster rockets.
Why do they have so many separate parts to fall off?
Rockets use lots of fuel. The weight of the fuel and oxygen is more than the weight of the rocket and cargo put together. So, not only does it take fuel to lift the space craft, but it takes more fuel to lift the fuel, and more fuel to lift that fuel: in other words, lots of fuel gets used up!

The three main shuttle engines use fuel fast enough to drain a 25m swimming pool in 25 seconds.

The shuttle fuel weighs so much that it can't lift it. The function of the booster rockets is to lift the fuel that the shuttle needs to lift itself into orbit. Once much of the fuel is used up, there is less weight and the boosters are no longer needed.

The booster rockets use 5 tonnes of fuel per second.

The Saturn V uses several stages so that as each stage runs out of fuel, it falls off, saving weight.

<u>The part in between launch and landing (why we are there in the first place).</u>

6a) Is there gravity in orbit?

Yes, there must be, otherwise what would hold the space craft in orbit around the earth? There is almost as much gravity in orbit as there on the earth's surface.

b) So, why does everyone seem to float inside the space shuttle?

Things seem to float, because they are always falling towards the earth (because of gravity). Since both the space craft and the things inside are falling down at the same rate, they insides seem to float. This is called free-fall.

Demonstrate with the book and the action figure.

7) So, if there is always gravity, how do space craft stay up?

See what they think.

a)What if we try to use the engines to hold us up?

Demonstrate with the eraser on a string.
Explain that the ball is the earth and the erasure is the space craft.

If we lift anything off the 'earth' it will fall back, in other words, our simulation has gravity.

We can use the engines to hold us up, but engines use fuel and we learned that it is too hard to carry much fuel into orbit. What happens when the fuel is used up.

Let go of the string to demonstrate.

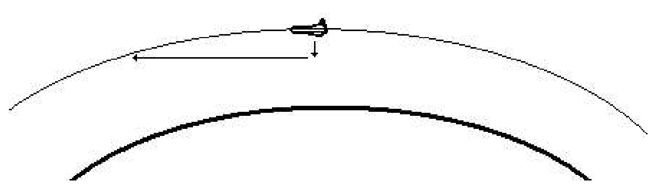
b) So, how can we keep up in space without needing to use fuel?

Let them mull this over for half a minute and if they don't figure it out, show them.

If we can't do it by constantly moving upwards, how about moving sideways.

Demonstrate by spinning the eraser around on the string. It stays 'up.' Since there is not air in space to slow us down (unlike in our simulation) it will keep moving without needing to use the engines.

Demonstrate on the black board



We fall a certain distance each second.
If we move very fast sideways each second, we can stay at the same height above the earth.

We must move very fast to do this: about 7.5 kilometres per second.

c) How do we get moving that fast?

The rocket engine.

It must get us up to orbit, but just as important, it must get us moving sideways really fast.

<u>Landing</u>

8a) What do we need to do in order to get back to earth?

We can't push downwards with our engines, that would actually get us higher. We can show you that later on our computer simulation.

b) What is holding us up?

Our sideways speed.

c) So, what do we need to do to land?

We need to slow our sideways speed.

9a) How do we slow down?
Use the last bit of fuel to start slowing down.
Cannot carry enough fuel up to slow down all the way (too heavy, remember).

b) So, what can we use to slow down?
Air resistance.
Slowing down a little bit gets us into the upper atmosphere, then air resistance starts slowing us down more.

c) What problem does air resistance cause?
It creates a lot of heat, enough to melt the whole shuttle.

10) What do we use to keep the shuttle from burning up?
Something that insulates, but is not too heavy.
The shuttle uses silica heat resistant tiles. They are mostly air with little strands of silica.
They are very light, but very good insulators.

Demonstrate with the tile and the propane torch.
Mount the tile in the clamp so it is horizontal (you might just leave it there for the day, explain that it is too delicate for them to touch).

Get an adult to hold the propane tank while you light the lighter, place it near the burner mouth, then just crack open the valve.

Once it is lit, put down the lighter, adjust the flame to a moderate flame, and aim it at the middle of the top surface of the tile (away from the metal clamp).

Get the adult to put their finger on the underside of the tile
(gently to avoid breaking it).

They should bring their finger in at right angles to the torch to that if the torch wobbles, it is much less likely that the flame will go near their hand.
They will feel some warmth, but the < 1cm thick tile will keep the >800 °C heat away from their finger.

After the torch is put out (close the valve), the adult can verify that the top of the tile is very hot, but the underside is still cool.

11) Once the shuttle is slowed down, all it needs to do is glide through the air on its wings to the landing site and land like an aircraft.

12) So, what did we learn today?
Get them to give you a couple of facts about each of the three phases of a space mission.

If there is time left, you can have them start planning and building balloon rockets. Have paper, scissors, tape and glue ready. We have all of that at 440 Albert already.

4) Sample Hardware Training Document

Sending Data between the Computer and Control Panels

The purpose of this document is to familiarize you with the strategies that we use to integrate our control panels, doors, and other electronic equipment with the computers and software on which we run our simulations. It is not designed to be a primer on basic electronics. For this, try:

http://www.kpsec.freeuk.com/index.htm
http://ourworld.compuserve.com/homepages/Bill_Bowden/page6.htm
http://www.play-hookey.com/digital/basic_gates.html

Our goals are to understand:

1) how to send signals to the computer and how receive signals from the computer
2) how the computer interprets the signals we send it
3) how to use different circuit components to manage these signals

Question 2: How Computers Manage Numbers

To understand how the computer interprets the signals going to and from our control panels, we need to know computers handle numbers. All of the signals that are control panels send to the computer or that the computer sends to our control panels are interpreted as numbers by the computer. Computers and people use numbers in much the same way, the only difference is the how many different numerals are used. We use 10 different numerals (0,1,2,3,4,5,6,7,8,9), computers use only 2 (0,1). Our numbers are ***decimal*** (10 numerals), the computer's are ***binary*** (2 numerals) The reason for using two numerals is that each corresponds to an electrical state in a circuit: ***on*** or ***off***, or if you want to think in terms of voltage, ***5 volts*** or ***0 volts***.

All of the signals (messages) that get passed around inside a computer are in the form of voltages on a wire. Cmponents in the computer (the central processing unit and the video card, for example) are connected to each other by wires (usually in the form of little lines of metal on a circuit board rather than loose plastic covered wires). The component sending a message does so by setting the voltage of the wire to either 5 volts (the computer equivalent of the number "1") or 0 volts (the computer equivalent of "0"). The component receiving the message reads it by registering the wire voltage. The information in the message is encoded in the pattern of voltage pulses: 5V, 0V, 5V, 5V, 0V, 5V, 0V, 0V,... rather like morse code. In terms of math, the computer's circuits interpret these pulses as 1,0,1,1,0,1,0,0,...

There is no special reason for using 5 as opposed to any other voltage; 5 volts is the voltage that most of the circuit components that we use were designed to work with. Lower voltages do not provide enough energy to power the component and higher voltages damage them. Thus, only two voltages are available, and so there are only two numerals for counting. In electronics, the negative voltage of a source (battery, generator etc.) is the zero voltage or ground voltage, and the positive voltage is the high voltage.

The circuit in figure 1 is a circuit in which the lamp represents the value of a one-digit binary number. The switch changes the value of the digit from 1 (high voltage) to 0 (low or ground voltage). The lamp only lights up when the switch is on the high voltage. The switch could just as easily switch from on (closed on +5V) to off (open). However, most of the integrated circuit chips that we use (more on these later) do not respond well to the open state. If they are getting neither a high or low voltage, their voltage tends to drift unpredictably. So, we give them an unambiguous voltage: 0V or +5V.

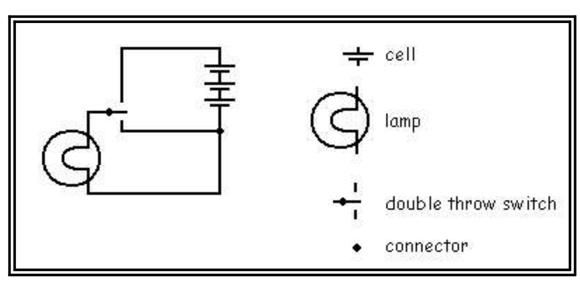


Figure 1
A circuit with a lamp indicating the state of a single digit binary number. The switch either contacts the + voltage wire or the - voltage wire. When lamp is on, this represents the numeral 1, when the lamp is off, this represents the numeral 0.

What is Moving in a Circuit

Electronics people think of positive charges moving around a circuit from the positive terminal of a battery (the longer of the two lines) to the negative terminal. Thus, the negative terminal is the zero-voltage point in the circuit (ground). The reason for this is that the first electrical circuits predate the discovery of the electron. These early electrical scientists had a 50% chance of picking the correct charge to move and they picked incorrectly (they did correctly conclude that only one charge moved). As far as the math is concerned, it makes no difference which you choose. In fact, in the semiconductor circuits, it does make sense to think of moving positive charges (more on this in another section).

Appendix D

Binary Numbers

In a number, each digit occupies a place in the number. Each place in a number corresponds to a multiplier which is a base raised to an exponent. The place multiplier is multiplied by the value of the numeral in that place and the product is added to the total value of the number.

In decimal numbers, the base used is ten. In binary numbers, the base is 2.

236 is a decimal number.

place	10 000s place	1000s place	100s place	10s place	1s place	total
multiplier	10^4	10^3	10^2	10^1	10^0	
numeral	0	0	2	3	6	
place value	0	+ 0	+ 200	+ 30	+ 6	= 236

With only two numerals, binary numbers require more digits to represent a given value than a decimal number.

11101100 is a binary number that represents the same value as 236 in decimal.

place	128	64	32	16	8	4	2	1	total
multiplier	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
numeral	1	1	1	0	1	1	0	0	
place value (decimal)	128	+ 64	+ 32	+ 0	+ 8	+ 4	+ 0	+ 0	= 236

Digits and Wires

In an electrical circuit, each digit of a number corresponds to the voltage of a wire. If you have a bundle of 8 wires, the biggest number that you can represent is an 8 digit binary number: any value from 0 to 255 (decimal), 0 to 11111111 (binary). Eight binary digits used to be the maximum size of number that computers could pass between the different components of the computer. In computer talk, the word '***bit***' is used to describe an individual digit. A group of bits that make up a number is referred to as a '***byte***.' Again, for historical reasons, the term byte almost always refers to 8 bits. The largest package of bits that the computer can handle as a single package is referred to as a '***word***.'

The reason that all this is important to us at space sim is because of the method that we use to communicate between computer and control panels.

The input/output (I/O) device that we use is the ***printer port***. This also is called the ***parallel port*** because it has 8 data wires so that it can pass numbers of 8 digits all at once along its 8 separate wires. The parallel port is what is known as a legacy port: it is installed on all computers but is rarely used these days except by older hardware (like us).

Serial ports and USB ports are more modern. They have fewer wires, so that they must send numbers as a sequence of digits one at a time. This makes life more complicated because the computer and hardware have to coordinate the passing of data very precisely. The parallel port sets voltages on the 8 wires and waits until the computer or hardware are ready to read the data. OCESS is presently converting many of their interfaces over to Arduino which allows us to use USB ports.

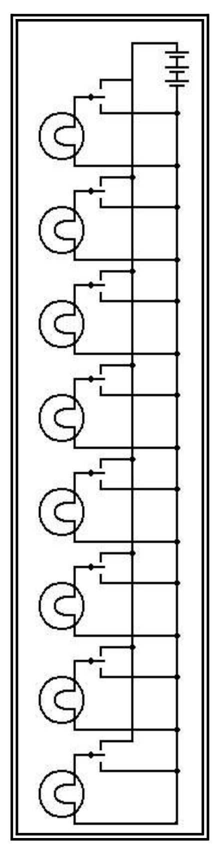


Figure 2
A circuit to represent a 8-bit binary number

The parallel port has 3 sets of 8 wires: 3 I/O bytes. One set, the data byte, is used to send character codes (each number between 0 and 255 specifies a different character to print). Another output byte, the control byte, is used to pass control codes to the printer (start a new page, for example) and also to equalize the two voltages (5V and 0V) between the computer and printer. The input byte is used to read messages from the printer (out of paper for example). In fact, the input and control bytes do not use all 8 wires. The unused ones are connected directly to the ground (0V) wire so that their voltage always is 0V. Why these wires are there at all is another strange bit of history, I am sure. The control byte uses only 3 wires and the input byte uses only 5. This limits the size of the numbers that we can pass on these bytes.

We need to learn binary about numbers because the computer deals with the input and output bytes as if they are numbers. It thinks that it is sends numerical data to the 'printer' and receives numerical data from the printer.

Sending Data to the Computer

On the input byte the computer hardware turns the voltages (+5V or 0V) on the 5 wires into a number between 0 and 63. In Figure 3, there are 5 switches on a control panel, each of which are connected to one of the wires of the parallel port's input byte wires. If the switch is flipped on, the wire is set to +5V, which the computer reads as "1." If the switch is set to off, the wire is set to 0V, which the computer reads as "0."

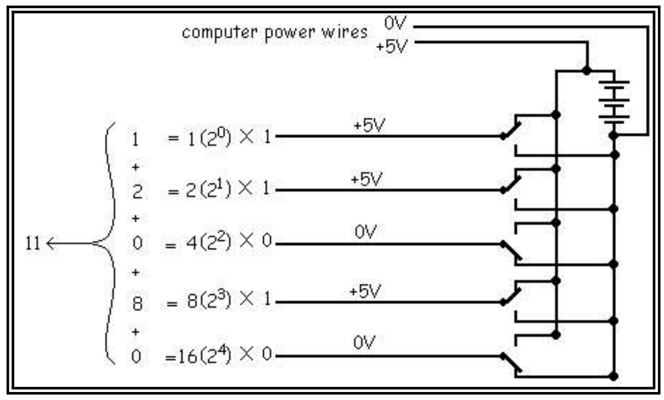


Figure 3
5 switches that communicate with a computer through the parallel port input byte.

In Figure 3, switches 1, 2, and 4 are on. Thus, the wires for 1, 2, and 8 are "1" and the wires for 4 and 16 are "0." The number generated is 1+2+8 = 11. Any other combination of switches will yield a different number in the input byte. Thus, the computer can know exactly which switches are on and which are off.

Just to keep things clear, the value of the multiplier is $2^{(n-1)}$ where "n" is the wire number.

Sending Data from the Computer

To send data on the control or data bytes, we send a number to the byte and it gets turned into 8 (or 3) different wire voltages.

In Figure 4, we have 8 LED indicator lights on a control panel. The power wire for each LED is one of the wires from the data byte of the parallel port. If the wire from the parallel port is at +5V, the LED lights up, otherwise it is dark.

To get the LEDs to light up, we send a number between 0 and 255 to the printer port (the computer thinks that it is printing a character on the printer). In the example in Figure 4, the number is 157. In binary, 157 is 10011101. This means that wires 1, 3, 4, 5, and 8 are at +5V and wires 2, 6, and 7 are at 0V. The 1st, 3rd, 4th, 5th, and 8th LED light up. Each number between 0 (all dark) and 255 (all lighted) will cause a different combination of LEDs to light up.

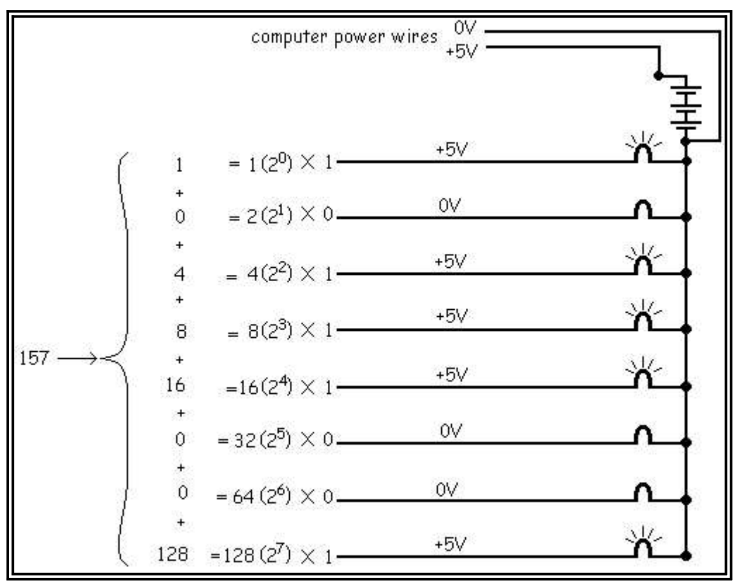


Figure 4
8 LED lights controlled by the data byte of the parallel port.

Reading signals from and Writing Signals to the Printer Port Using Software

The computer has an identifying number for each of its input and output ports (devices that take in signals or send out signals). In PC compatible computers the port numbers for the primary printer port (LPT1:) are 888 (data byte), 889 (input byte), and 890 (control byte).

Each computer language has its own commands for sending data to and from the port. The easiest way to send signals to the data port is to print a character. For example, the command in BASIC:

```
PRINT "A"
```

would send the following signal to the data byte: 01000001, turning on the 1st and 7th LEDs in figure 4. This is because the character "A" is character number 65 in the ASCII (American Standard Code for Information Interchange) character list. The number 65 decimal is equivalent to 01000001 in decimal.

Sending Data from the Computer

However, it is inconvenient to remember all the ascii codes and this method does nothing to help us use the control and input bytes. Fortunately, computer languages have more generic commands for reading data from and writing data to ports. In BASIC, the command:

```
OUT 888, 65
```

would send the same signal to data byte as PRINT "A".

All that we need to do is generate a number that represents the state of our 8 LEDs. If the state of each LED is given by a variable state(i) where 'i' is the LED number, then the following would code in BASIC would set each of the 8 LEDs in figure 4 on or off as specified by the value of the variable state(i) for each LED.

```
LEDstatus=0
FOR i = 1 to 8
  LEDstatus = LEDstatus + (state(i) * (2^(i-1)))
NEXT i
OUT 888, LEDstatus
```

In the case of Figure 4, LEDs 1, 3, 4, 5, and 8 are supposed to be on. So, state(1), state(3), state(4), state(5), and state(8) will be set to "1" by the software before we get to this part of the program. The variables state(2), state(6), and state(7) would be set to "0."

When i=1, (state(i) * (2^(i-1))) works out to 1 X 2^0 which equals 1. So we add "1" to LEDstatus

When i=2, (state(i) * (2^(i-1))) works out to 0 X 2^1 which equals 0. So we add "0" to LEDstatus

When the For-Next loop is done, LEDstatus will equal 1+4+8+16+128 = 157 and we send the number 157 to the data byte to turn on LEDs 1, 3, 4, 5, and 8.

<u>Sending Data from the Control Panel</u>
To read data from the input byte (port number 889) , BASIC also has a command.

```
INP(889)
```

This expression is treated as a variable by the BASIC language. If the number that we read is "10," for example then the 2nd and 4th switches are on and the 1st and 3rd are off. This is because the number "10" in binary is 1010.

You might think that it will be a pain to convert every number we read from the input port into binary then figure out which places are "1" and which are "0." However, BASIC includes a handy little command that takes care of that.

```
IF (2 AND 10) = 2 THEN...
```

This command compares the place values of the numbers 2 and 10. It looks at all the places that are "1" in both the numbers 2 and 10. If these places add up to 2, then it executes the code after "THEN". In this case, the answer would be 2 and the code would be executed.

```
                 b)   0010
                10:   1010
places in common:     0010  =  2      therefore, (2 AND 10) = 2
```

If we tried IF (3 AND 5) = 3 THEN... the expression would not be true and the code after "THEN" would not be executed.

```
                 3:   0011
                 5:   0101
places in common:     0001 = 1        therefore, (3 AND 5) = 1
```

So, to read the signals from 5 switches through the input byte (as in Figure 3) and figure out which switches are "on" or "off," we would use the following code. The status of a switch is stored in a variable called switch(i) where 'i' is the switch number. If the switch is on, the variable is set to "1." If the switch is off, the variable is set to "0."

```
SWITCHstatus = INP(889)
FOR i = 1 to 5
  IF (SWITCHstatus and (2^(i-1))) = 2^(i-1) THEN switch(i)=1 ELSE switch(i)=0
NEXT i
```

Since, in Figure 3, switches 1, 2, and 4 are on while switches 3 and 5 are off, we get the number 01011 binary or 11 decimal sent in on the input byte. In our software, the first line would result in SWITCHstatus variable being set to "11." The FOR-NEXT loop would make the following 5 comparisons:

$2^0 = 1$; If (11 and 1) = 1; the answer is yes, therefore switch(1) =1
$2^1 = 2$; If (11 and 2) = 2; the answer is yes, therefore switch(2) =1
$2^2 = 4$; If (11 and 4) = 4; the answer is no (it equals 0), therefore switch(3) =0
$2^3 = 8$; If (11 and 8) = 8; the answer is yes, therefore switch(4) =1
$2^4 = 16$; If (11 and 16) = 16; the answer is no (it equals 0), therefore switch(5) =0

So our software is able to tell that switches 1, 2, and 4 are on and switches 3 and 5 are off.

Irritating Issues

There are two issues that complicate what we do with inputs and outputs.

1) If you look at Figure 5, you will see that the input byte has pins for bits 3,4,5,6, and 7. Bits 0, 1, and 2 are the ones that are left out rather than bits 5, 6, and 7. This just changes our code a bit. Instead of comparing our SWITCHstatus variable to 2^{i-1}, we need to compare it to 2^{i+2} instead

2) For some strange reason, the computer hardware inverts the signal on pins 11, 14, and 17. That is, if 5 volts comes in on that pin, the parallel port hardware assigns a value of “0” rather than 1 and if 0 volts comes in, it assigns a value of “1.” Mystifying, irritating, but easily dealt with in the software. No changes to the hardware are made to deal with this issue.

Connecting Control Panel Switches to the Computer

As you already know, we have 5 input pins on the LPT 1 (printer) port with which to send signals from switches to the computer. Five switches is not a very complicated control panel; we need dozens. One possibility is to install more parallel port cards into our computers, but this is expensive and difficult, since printer ports are not commonly sold anymore and our older computers make it hard to install these cards because there are only so many interrupts (interrupts are the coded signals that the peripheral cards use to tell the main processor of the computer that they have something to send it). Not only that, if we installed two more parallel ports (the maximum that can be installed) that would only give us 15 inputs in total; still not a very complex panel.

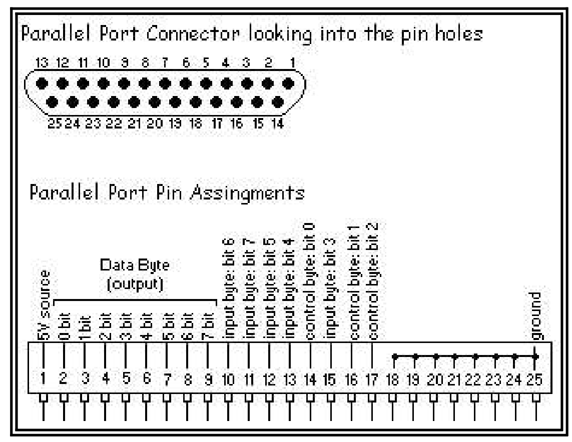


Figure 5
Parallel port pin assignments

A better method is to send lots of signals to the parallel port a few at a time over a smaller number of input bits. There is a very handy chip that allows us to do this: the ***multiplexer***. The multiplexer is an integrated chip with 16 pins in two rows: a dual inline pin, or DIP chip (Figure 6). Integrated chips are named such because they have many different components integrated into one unit. We use a number of different types of chip in our control board circuits.

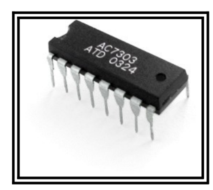


Figure 6
Typical DIP integrated chip

Multiplexers

A multiplexer takes in two groups of 4 inputs: group A and group B (there are other varieties with different numbers) and sends them to 4 outputs one group at a time. So, we can send 8 separate signals from 8 separate switches: A1, A2, A3, and A4 in one group and B1, B2, B3, and B4 in the other group (Figure 7). Which of the two groups gets sent on to the parallel port depends on the value of a selector input. If the selector pin is set to 0V, then it is the signals from group A that get sent on. If the selector pin is set to 5V, then it is the signals from group B that gets sent on. The selector pin gets its signal from one of the output bytes of the parallel port (Figure 8).

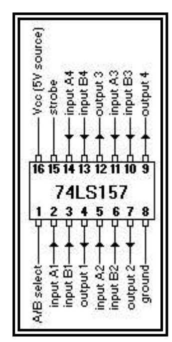


Figure 7
Multiplexer Integrated Chip type 74LS1157 pin assignments

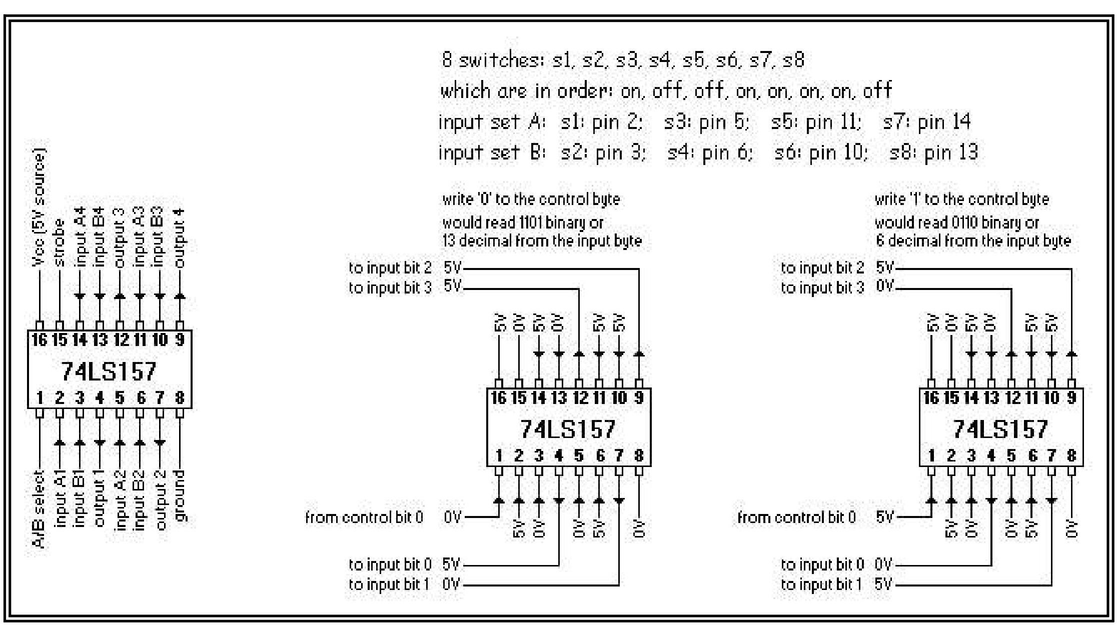


Figure 8
8 switches routed through 1 multiplexer in 2 groups of 4

To operate the multiplexer (Figure 8), the 4 output pins are connected to 4 of the 5 input pins in the parallel port. The selector pin is connected to one of the 3 control pins (output). In the example in Figure 8, the selector pin of the multiplexer is connected to the pin for bit 0 of the control byte. If we write the number “0” to the control byte (000 binary), bit 0 of the control byte will have the value “0” and the selector pin of the multiplexer will be set to 0 volts. This will cause input group A to be sent to the output pins of the multiplexer and, thus, on to the input byte of the parallel port.

Input Byte:	bit 3	bit 2	bit 1	bit0
Signal at Bit	5V	5V	0V	5V
Bit Value	1	1	0	1
Binary Value at Input Byte	1101			
Decimal Value at Input Byte	13			

As shown in Figure 8, if switches in group A, (switch numbers 1, 3, 5, and 7) are ***on***, ***off***, ***on***, and ***on*** respectively, then the signals to the 4 bits of the input byte will be 5V, 0V, 5V, and 5V (starting with bit 0). This means that when we set the control byte to “0” and read the value of the input byte, we will see the number 13. The computer sees the binary number 1101 and knows that switches 7, 5, and 1 are on.

If we write the number “1” to the control byte (001 binary), bit 0 of the control byte will have the value “1” and the selector pin of the multiplexer will be set to 5 volts, instead of 0 volts. With this setting, the multiplexer will send data set B (switches 2, 4, 6, and 8) on to the parallel port, rather than set A. Since these four switches are, in order from 8 to 2, ***off***, ***on***, ***on***, and ***off***, the value of the input byte will be 0110 binary, or 6 decimal.

<u>Multiple Multiplexers</u>
What if we have more than just 8 switches? We can use groups of multiplexers to handle very large groups of switches (Figure 9). For 16 switches, we need 3 multiplexers. The 16 switches send their signals to one of two multiplexers. Each of these sends either one group of 4 or the other to the third multiplexer. The first two multiplexers send either data group A or B depending on the signal they get from bit 1 of the control byte. The third multiplexer sends along the data from either multiplexer 1 or 2 depending on the signal it gets from bit 0 of the control byte. Thus, the computer must read the input byte from the parallel port 4 times to get the information from all 16 switches. Before each reading, we must send a value to the control byte to set the three multiplexers: 0, 1, 2, and 3 decimal (00, 01, 10, and 11 binary). Each of these 4 control byte values causes a different set of switches to be read by the computer.
If we have more than 16 switches, we just use more multiplexers.

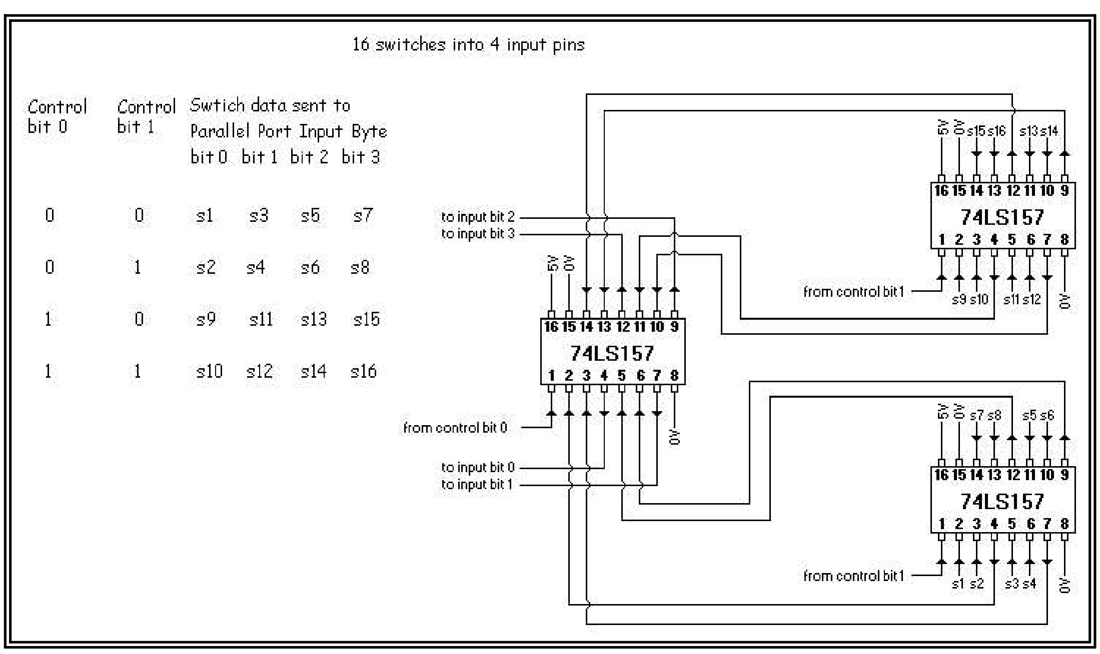


Figure 9
Signals from 16 switches sent to 4 parallel input pins in groups of 4 by three multiplexers.

<u>Connecting Control Panel Indicator Lights to the Computer</u>
Many of the indicator lights on a control panel can be set by the switches themselves (most of our switches are double pole, which means that one pole can send a signal to the computer and the other can send a signal to an indicator light). However, there are many functions that the computer software manages for which we want to have indicator lights. To do this, the data byte on the parallel port can be used to turn light emitting diodes (LEDs) on and off. The low voltage end of the diode is connected to ground (0V) and the high voltage end of the diode is connected to the output pin of the parallel port. When the pin is at 0 volts, the LED is off. When the pin is at 5V, the LED is on (see Figure 4).

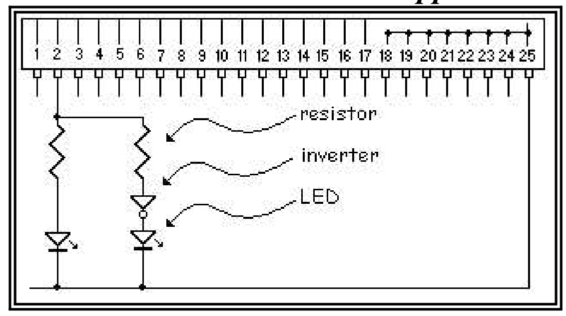


Figure 10
LEDs wired into a parallel port circuit. Using the inverter, one and only one of the LEDs is on at a time. If the left-hand LED is on, the inverter is getting a 5 volt signal and puts out a 0 volt signal so the right-hand LED is off. If the left-hand is off, then the inverter is getting 0 volts and puts out 5 volts, turning the right-hand LED on.

LEDs are designed to work with about 2 volts, so a resistor is wired in series with the LED to drop the voltage and avoid damaging the LED. We also want to limit the current that the parallel port must supply. If the port draws too much current, the motherboard of the computer can be destroyed.

The maximum current that the LED needs is 0.02 amps and we need a resistor that will use up 3 volts ($5\ V_{supply} - 2\ V_{LED} = 3\ V$). We can use Ohm's law to calculate the necessary resistance.

$$R = V/I = 3V/0.02A = 150\ \Omega$$

Alternating LEDs

Often, it is desirable to have an LED to indicate when some function is on and a separate LED to indicate that it is off (you would not want to have a damaged LED fool you into thinking that a function was off when it is not). A good example of this is our door circuit where we have a red LED to tell us when it is not safe to open a door and a green LED to tell us when it is. However, we do not want to tie up two parallel ports for this function nor increase the complexity of the software by programming two LEDs.

To have an ***on*** and an ***off*** LED, we use a circuit component called an inverter (also called a NOT gate). The inverter puts out a signal that is the opposite of the signal that it takes in. If its input pin is a 5 volts, it output pin is at 0 volts. If its input pin is at 0 volts, its output pin is at 5 volts (see Figure 10). Inverters come in integrated chips with 6 separate inverters: a hex inverter (see Figure 11).

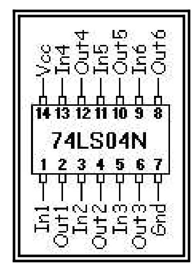


Figure 11
74LS04 hex inverter

More Than 8 LEDs

As with switches, usually we have more LEDs on our control panel than we have output ports on the parallel port. We need to do what we did with the switches, but this time, we need to send our 8 bits of data to 8 LEDs and have them remember whether they are supposed to be on or not while we use the same 8 output bits to send signals to 8 more LEDs. We need a memory chip that can remember a set of signals. There are a multitude of different types of memory, all packaged into DIP integrated chips.

Memory Latches

I think that the easiest type of memory chip to use is the latch. Some of the others probably are easier once you figure them out, but they don't look that easy to me! You need to keep in mind that I am in the process of learning this stuff as well. An individual memory latch has an input and an output. The memory latch chip also has a latch enable pin. When the latch enable pin is at 5 volts, the output will be the same as the input. As soon as the latch enable pin goes to 0 volts, the output pin holds what ever voltage was at the input pin when the latch enable pin was still 5 volts. Actually, there is a small time lag of a few nanoseconds after the latch enable pin goes to 0 volts during which we need to keep the input pin at our desired voltage.

Steps in the Memory Latch Process

Step 1) Set the input pin(s) to 5 volts or 0 volts as desired (Figure 12).
Step 2) Set the latch enable pin to 5 volts.
This can be done using one of the wires from the control byte.
The corresponding output pin(s) will match the input pin(s).
Step 3) Set the latch enable pin to 0 volts.
Wait 20 nanoseconds (take care of this in the software).
Step 4) The input pin(s) now can be set to either 5 volts or 0 volts, but the output pins will remain at the voltages that they had in step 2.

To reset the output pin(s), repeat the process from step 1.

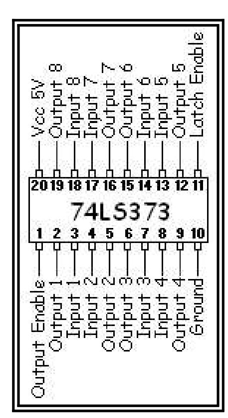


Figure 12
74LS373 octal memory latch

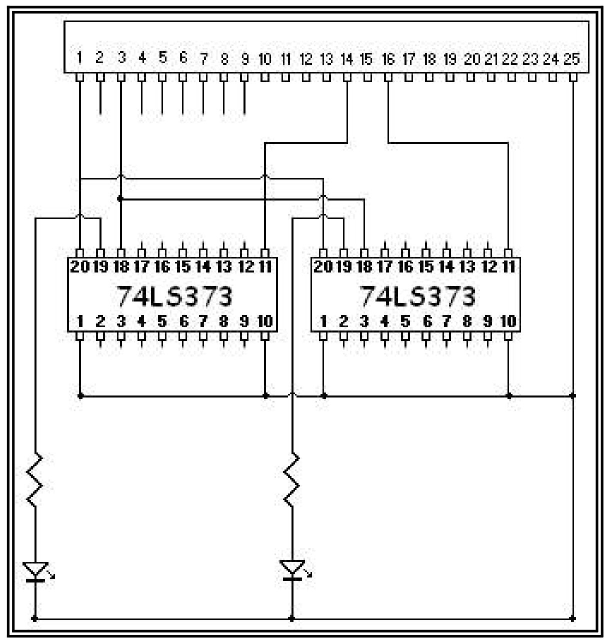


Figure 13
2 octal memory latches allowing 1 output pin to control two LEDs independently. The left-hand memory latch is controlled by the output from pin 14 on the parallel port; the right-hand latch from parallel port pin 16.

The output pins on the memory latch chip can sustain enough current to operate an LED or to hold a parallel port input pin at a given voltage. This means that we can use the 8 pins of the parallel port's data byte to set output pins on one memory latch, then use the same 8 parallel port pins to set the output pins on a different memory latch (Figure 13).

In Figure 13, we only are showing the output from parallel pin 3 only to keep the picture clear. This parallel port output sends a signal to both memory latches simultaneously. However, they ignore it, unless their latch enable pin (pin 11 on the chip) is set to 5 volts.

To set the output pin (pin 19 in this case) on the left-hand memory latch, parallel port pin 14 is set to 5 volts and parallel port 16 is set to 0 volts (see Figure 5 for parallel port pin assignments). We do this by writing the number 1 decimal (001 binary) to the control byte of the parallel port. Now, pin 19 on the left-hand memory latch will adopt what ever voltage is coming from parallel port pin 3. Then, we write 0 decimal (000 binary) is written to the control byte. Pin 19 on the left-hand memory latch will maintain it current value and the left-hand LED will stay on or off as desired. The voltage on parallel port pin 3 is changed to the value we want for the output of the right-hand memory latch. Then, we write the number 10 decimal (010 binary) to the control byte of the parallel port and output pin 19 on the right-hand memory latch will adopt the voltage of parallel port pin 3, turning the LED on or off. We then write the number 0 decimal (000 binary) to the control byte and the two memory latches will keep their respective voltages and the LEDs will keep their current status until we want to change them.

Controlling Higher Voltage and Current Devices

The 5 volt logic components (parallel port pins, memory latches, etc.) cannot power higher voltage components like our 28 V warning lamps, nor can they power high current (low resistance) components. To switch these on and off using the computer we have two choices: transistors and relays.

Transistors

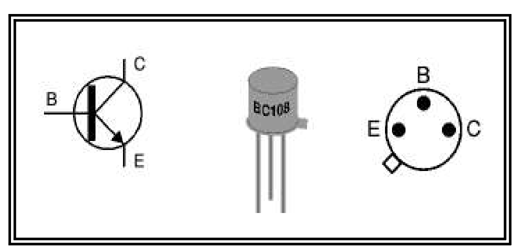


Figure 14
Left: circuit symbol for an NPN transistor.
Center: a typical metal capped transistor.
Right: use of metal tab to identify the thee leads when viewed from the bottom.

Transistors are like an electronic switch. They have three wires: the collector (C), base (B), and emitter (E). There are two types of transistor: NPN and PNP. NPN transistors are more common, cheaper, and do exactly what we need to get done.

It is important to keep straight which pin is which because transistors are destroyed easily if they are not connected correctly.

The main current that the transistor is controlling flows from the collector to the emitter. No current will flow, however, unless a small voltage is applied to the base. When this happens, current can flow from collector to emitter and from base to emitter. The collector, emitter, and base do not have to be at the same voltage, but there are limits to the voltage difference, especially between the base and emitter. For this reason, these transistors usually are placed after the main load. Careful reading of transistor specifications and planning of the circuit is necessary to avoid transistor damage.

A transistor allows a low voltage circuit, such as a 5 volt parallel port, to turn a higher voltage circuit on and off (Figure 15). Thus, we have a controlling circuit (the parallel port circuit) and a controlled circuit (the lamp and battery).

The current from the base and the current from the collector both pass through the emitter. For this reason, the two circuits must share a common ground so that the two currents can separate and complete their individual circuits.

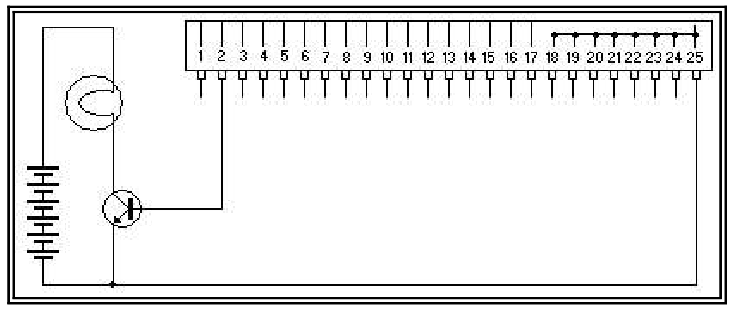


Figure 15
Using a parallel port output pin to turn a transistor on or off, which, in turn, turns a battery powered lamp on or off. Writing 1 decimal (00000001 binary) will turn the lamp on (the transistor base is at 5 volts, which lets current flow from collector to base). Writing 0 decimal (00000000 binary) turn the lamp off (the transistor base is a 0 volts).

Relays

There are situations in which it is not possible or advisable to the controlling circuit and the controlled circuit to share a common ground. This could be because the controlled circuit is alternating current or because it has a higher voltage or current than a transistor can manage. A relay, like a transistor, is a switch. Relays have the advantage that they maintain complete separation between the controlling and controlled circuits. Relays are much larger than transistors, they are slower to switch on and off, and they consume more power (Figure 16).

Figure 16
Typical relay

Relays use an electromagnet to flip their switches between the on and off position. The electronmagnet is a coil which is powered by the controlling current. The magnetic field created by they coil causes the switch attached to the main current (the controlled current) to flip positions. This switch is a double throw switch (like in Figure 1). The control switch can be wired so that the coil can either turn the main switch on or off. One wire for the controlled circuit always is attached to the common lead of the relay. The other wire for the controlled circuit is attached to the Normally Open lead (NO) if the circuit is supposed to off most of the time and only turned on by the controlling circuit. Alternately, the controlled circuit can be attached to the Normally Closed (NC) lead if the controlled circuit is supposed to be on most of the time (Figure 17).

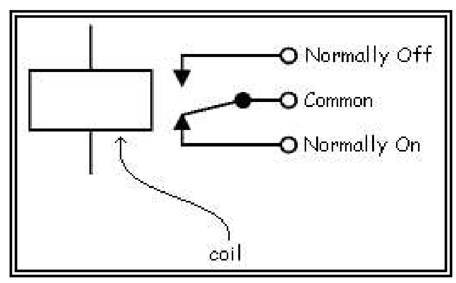


Figure 17
Circuit diagram for a relay

Controlling a Relay

Relays usually need a larger voltage and current to activate the coil than can be provided by a 5 volt logic circuit. So, the parallel port or other 5 volt signal is used to turn on a transistor which, in turn, activates a larger current to activate the relay coil (Figure 18). In addition to the transistor, a diode must be used, wired in reverse, to divert the current spike that accompanies the turning off of the relay coil. This *protection diode* prevents the sensitive logic circuit components from a dangerous spike in voltage that would occur without it each time the relay was turned off.

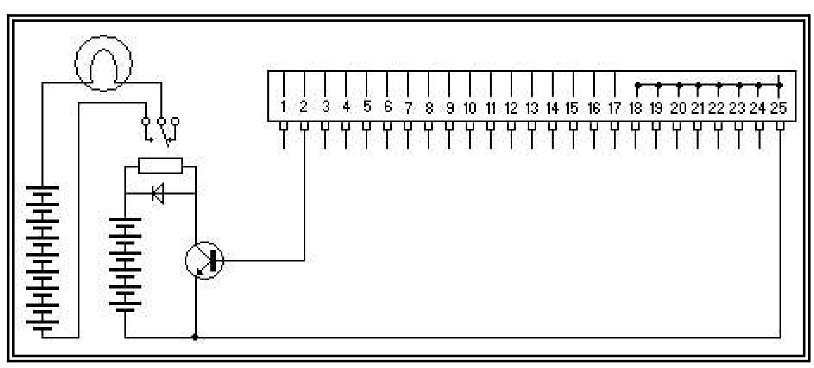


Figure 18
A 13.5 volt circuit powering a lamp which is turned on by the activation of a relay. They 9 volt relay circuit is turned on by a transistor which is activated by an data pin from the parallel port. When a "1" is written to this pin in the software, the pin goes to 5 volts, which activates the transistor, which activates the relay. The lamp circuit is wired to the NO lead of the relay which means that the circuit is open unless the relay is activated.

For even greater separation of the controlled circuit from the controlling computer circuit, one can use an optocoupler to power the transistor. An optocoupler takes the 5 volt signal from the parallel port and uses it to power an LED. The light from the LED powers a photodetector which converts the light energy back into electrical energy. Thus, even if the insulation in the relay shorts out, the computer still is protected from the dangerous voltage in the controlled circuit.

With a relay, we could use the computer's parallel port to switch power to the habitat's three electrical circuits on and off. We also could use relays as sensors to detect when those same electrical circuits are switched on or off at the circuit breaker.

Appendix D

Space Sim Circuits

The door circuit card does is not an interface for a control panel, rather it is an interface for the computer and the doors. In essence, each door constitutes a mini control panel as it has one switch which opens and closes with the door and two pairs of LEDs to indicate if it is safe to open the doors or not. All of the components are similar to ones which we have discussed, with the exception of ***pull-up resistors*** which are attached to the 4 input pins.

Pull-up Resistors

The door switches connect the input pins on the multiplexer to the ground wire (0 volts). When the door is closed, its input pin on the multiplexer goes to 0 volts and, as a result, so does the corresponding input pin on the parallel port. But, when the door is open, there is nothing holding the input pin at any particular voltage. As a result, its voltage will tend to drift. We actually want the input pin voltage to go to 5 volts so that it will be different from what it is when the door is shut (otherwise the computer cannot tell the difference between shut and open). To make the input pins go to 5 volts when the doors are open, we attach the input pins to the 5 volt wire using high resistance resistors (about 3000 ohms). These are sufficient to keep the input pins at 5 volts when the doors are open with very little current, but have too much resistance to stop the switch from dragging the input pin to 0 volts when the door is closed.

Supplemental Current

Another addition to these circuits is that we draw electrical power from the computer's power supply directly in order to supplement the current that the parallel port must supply. The connection is in parallel (remember grade 9?) so that the parallel port only has to supply part of the current.

Decoupling Capacitors

All the chips on a circuit board create little voltage spikes when they switch input and output states. Other chips can erroneously interpret these spikes as data and we can end up getting strange results in our circuits. To counteract this problem, most experts advise the use of decoupling capacitors.

A capacitor is like a small rechargeable battery. It consists of 2 metal plates separated by a thin layer of insulating material. One plate is attached to a negative voltage, the other is attached to a positive voltage. The negative voltage of the negative plate drives electrons out of the positive plate (giving it a net positive charge), and the positive voltage of the positive plate attracts electrons into the negative plate (giving it a net negative charge). The motion of electrons into one plate and out of the other causes a current in the circuit. When the repulsion of the charges within each plate equals the attraction to the opposite plate, no further movement of charges takes place and the current caused by the capacitor stops.

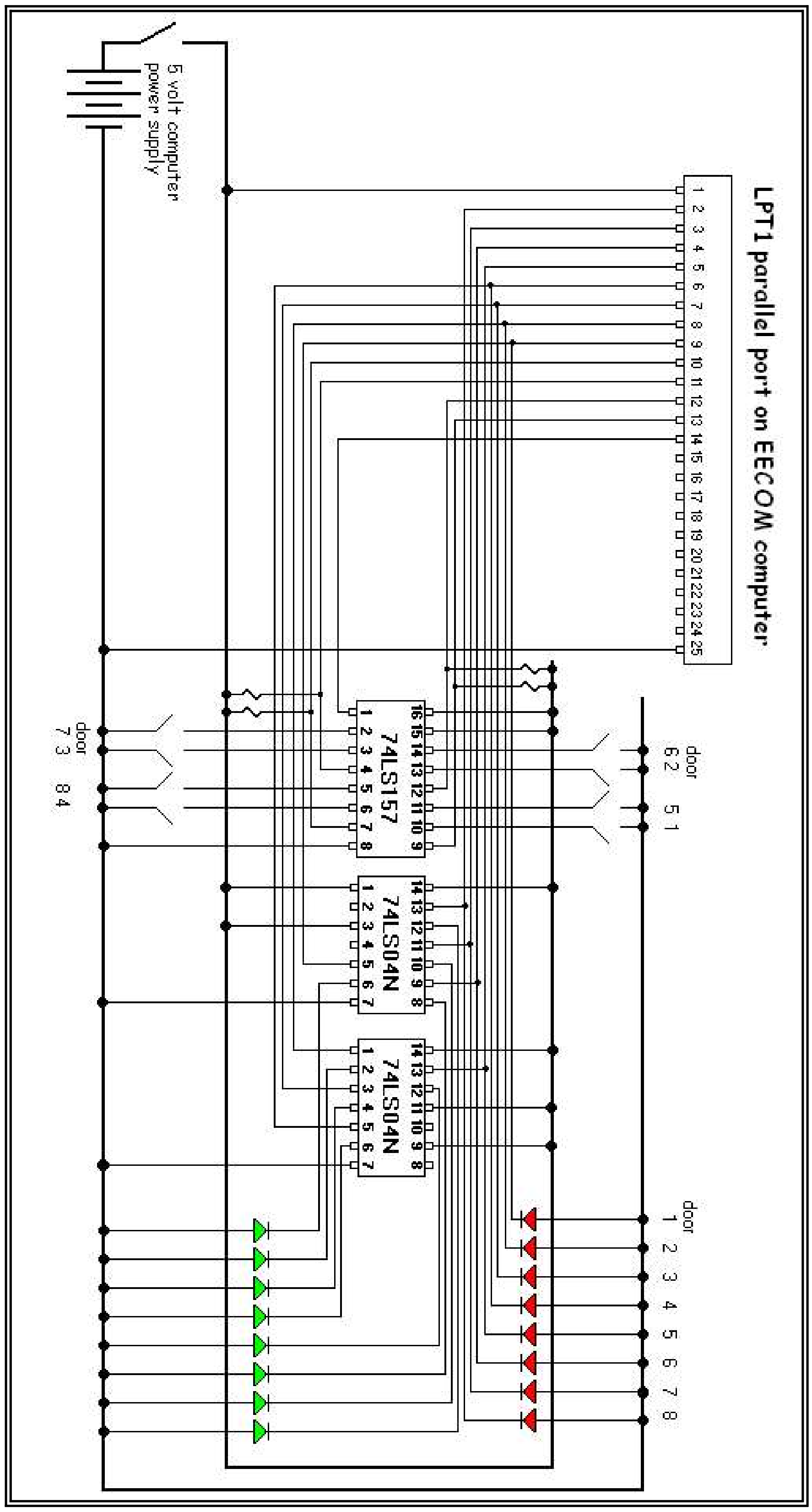
If the battery that supplied the voltage is disconnected, there is no longer any voltage to overcome the mutual repulsion of the charges in each plate. The extra electrons move out of the negative plate through the circuit and back into the positive plate so that both plates are neutral again. While this is going on, a small current will be caused in the circuit by the capacitor.

So, capacitors store charges whenever the voltage of the circuit increases and release it when the voltage decreases. In other words, they are like a small sponge for current. If there is a small spike in voltage in a circuit, the capacitor will soak up the current that this voltage spike creates and release it when the voltage goes back to normal. Thus, the effects of the voltage spike are reduced by being spread out over a much longer time interval. Very clever!

The decoupling capacitors are connected between the supply and ground pins of the integrated chips on a circuit board. Usually only 1 decoupling capacitor is needed for every 4 chips to be effective. We do not have any decoupling capacitors in our circuit boards, but we may find that we have to add them.

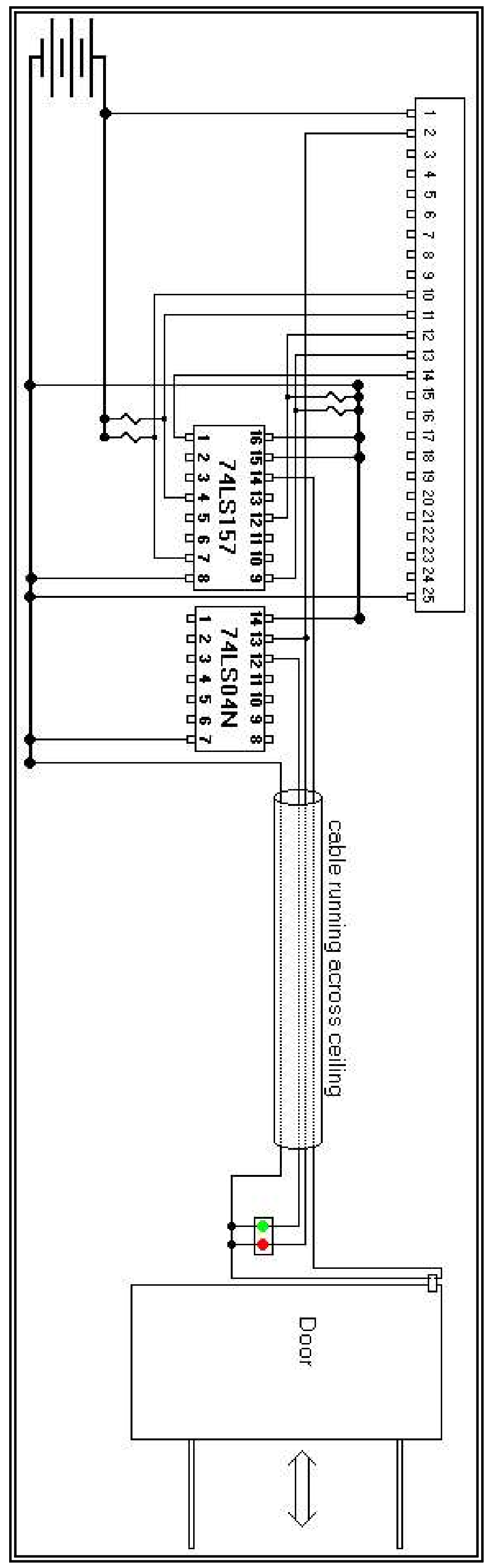
Door Circuits

Each of the 8 doors sends a 0 volt signal to the input byte of the parallel port when the door is closed. Otherwise, the input pins are held at 5 volts. The 8 data byte pins are used to send a 5 volt signal each of 8 red door warning lights as well as to 8 inputs on the two hex inverter chips. If the data byte pins are at 5 volts, the red LEDs light up and the inverter puts out 0 volts to the green LEDs. If the data byte pins are at 0 volts, the red LEDs are dark, but the inverter output pins go to 5 volts and the green LEDs light up.



Appendix D

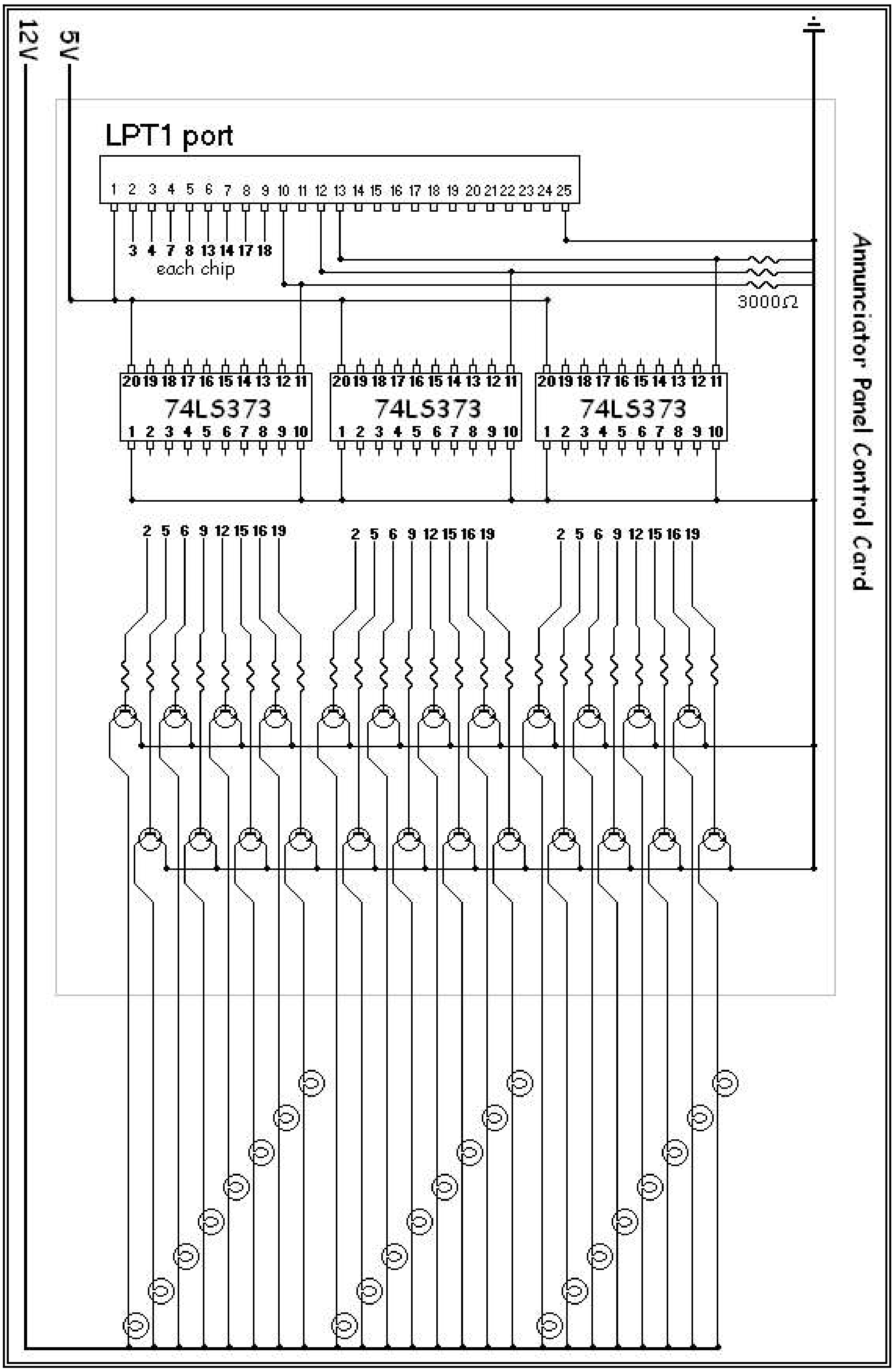
The actual physical arrangement of the components of the door circuit is as follows. The three chips are on the interface card plugged into the computer. The LEDs and the switch for the door are at the door itself (only one hex inverter and 1 door are show for clarity). The door switch and the two LEDs share a common ground wire. When the door is closed, so is the switch and the input pin at the multiplexer is drawn down to 0 volts. The multiplexer output pin is also drawn to 0 volts when the appropriate input group is selected. Since the multiplexer output pins are otherwise held at 5 volts by the resistor attached to the 5 volt source wire, the computer knows whether the door is open or not by the value it reads from the input byte. The EECOM software determines which LED should be on and writes the appropriate number to the data byte of the parallel port.



Appendix D

Warning Light Panel

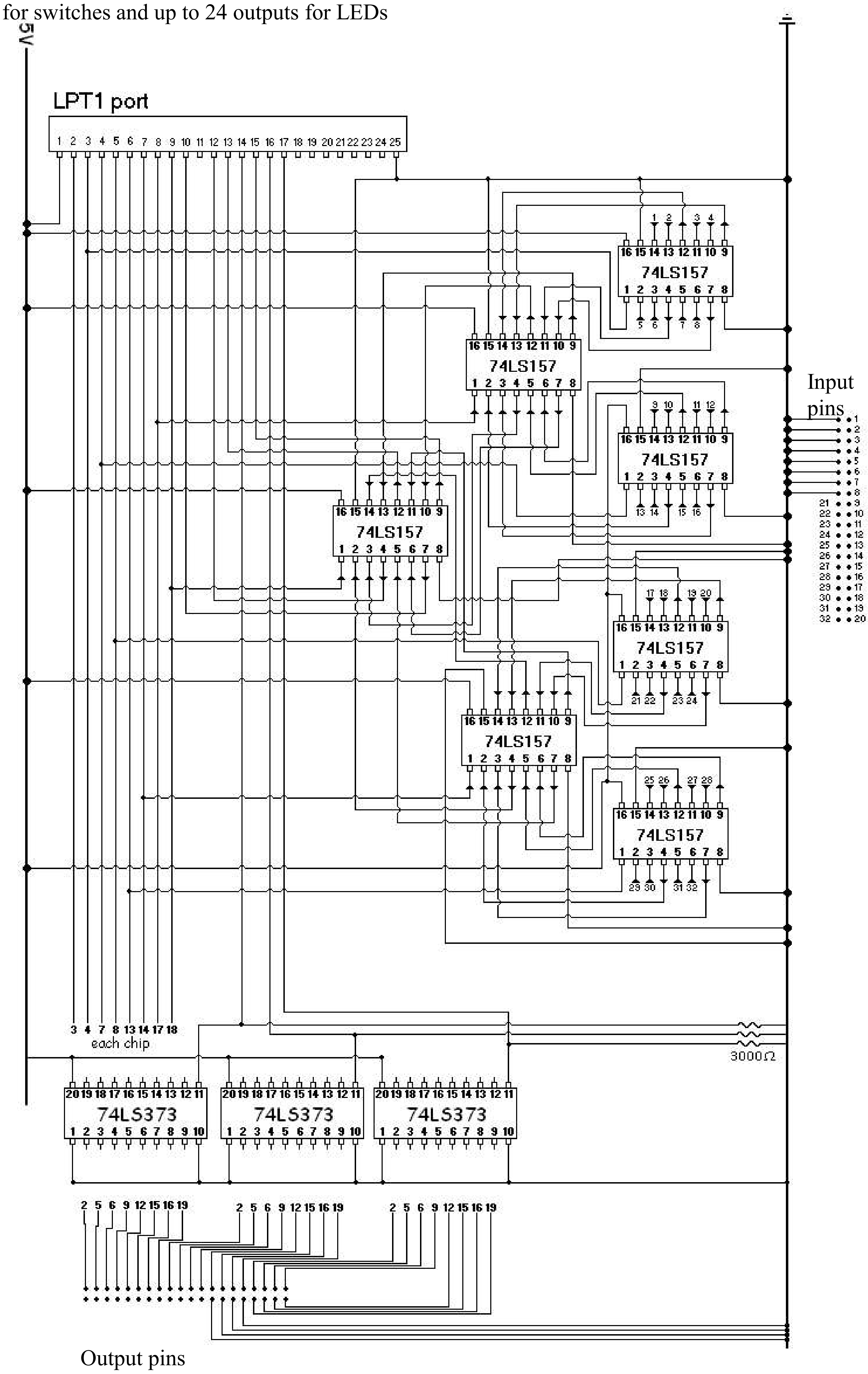
The warning light panel has 24 red lamps that will run on the 12 volt supply voltage from the computer's power supply (they are designed to work on 28 volts, but they are bright enough at 12). They get their signal from the sim computer running the their version of the orbit software. Each data pin sends a signal to the same input pin on three memory latches. The three pins of the control byte are used to enable and disable the latching function of the memory latch chips so that only one latch actually reads the data at a time. For clarity, the data connections to the memory latch chips are not shown, but the pin numbers show where each wire is to be connected.



Appendix D

Orbit Computer I/O card

Circuit diagram for a generic card to allow the orbit computer up to 32 inputs for switches and up to 24 outputs for LEDs



This card design is being replaced by modified keyboard interface cards and Arduino devices.

5) EEP Physical Solar System Simulations

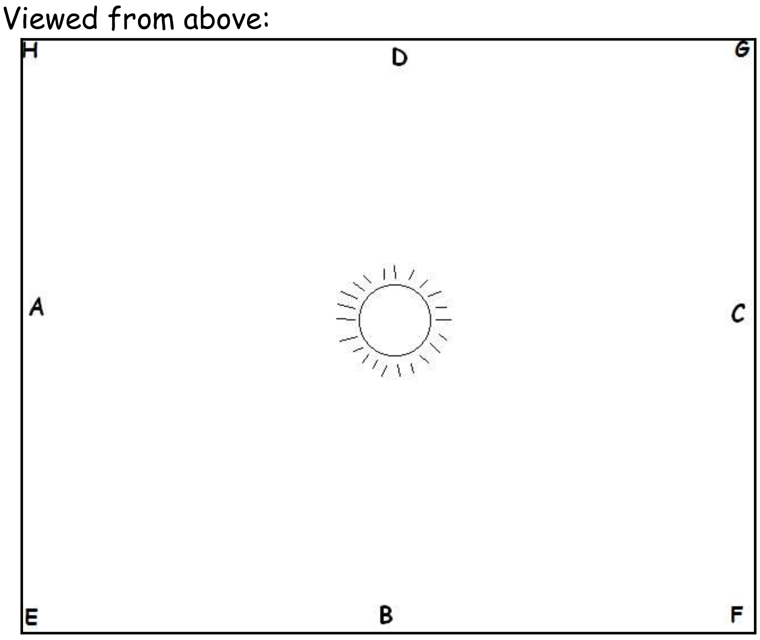
Solar System Modeling Activities

Preparation

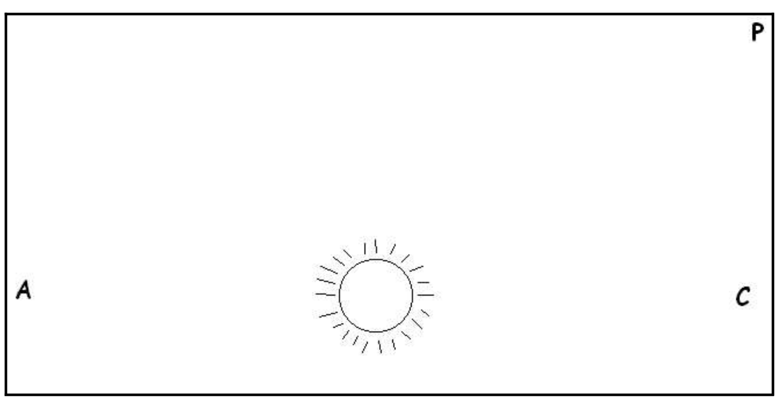
1) In the center of an open room, place a lamp. This represents the sun. It need not be plugged in, but it is a better effect if it can be turned on and the other room lights turned off.

2) Set up sheets of paper with letter labels on the walls of the room as shown in the following diagrams. These sheets of paper represent stars. For star 'P,' a couple of metre sticks can be taped together to allow the paper to be pushed into place high on one wall above star C.

Viewed from above:



Viewed from the side of the room



Other materials inculde:

3) a large balloon or exercise ball to represent the earth with labels for
- north pole (N) - a circle around the equator
- south pole (S) - an 'X' for Ottawa (about ½ way between N and the equator)

Looking down on the 'earth' from above the north pole, label the right-hand side of the X with a 'W' for the west direction and the left-hand side of the 'X' with a 'E' for the east direction.

If using a balloon, taping the south end to a metre stick helps make handling it easier while keeping it visible for the students.

Blow up a smaller balloon and tape it to another metre stick at the tied-off end of the balloon.

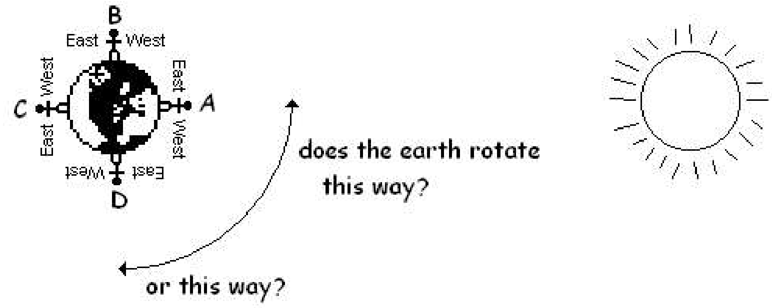
Make a sheet of cardstock with a 2 cm circular hole cut out of the centre.

4) Make little person figures out of masking tape to attach to the earth. You should be able to remove and reattach it facing in different directions.

5) As much as possible, try to have the students manipulate the model earth.
This keeps them focused and helps them see sky from the perspective of the person figure.
Have one or more of the students keep records on a blackboard or white board.
- this should include sketches of what would be seen from the view point of the figure.

Appendix D

I) <u>Time of Day Activity</u>:



1) Attach a person figure to X
   If the Sun rises in the east and sets in the west, what direction must the earth be turning:
   west to east? (counter clockwise looking down from the top) **<u>or</u>**
   east to west? (clockwise looking down from the top)

Start the X so that it is just in the dark half of the earth and rotate the earth so that it reaches the terminator (the place where the light half and the dark half meet).
Do this starting near position B rotating clockwise and near position D rotating counterclockwise.
Which results in the person at X having to look to the east to see the rising sun?

What determines the time of day?
2) Orient the 'earth' so that X is in position A for the diagram above.
   You should place the earth between the sun and star A pointing north up towards star P.
   a) What direction does the person have to look to see the sun?
      They should be able to deduce that the person needs to look straight up.
   b) What time of day is it?
      They should be able to deduce that this means it must be noon.

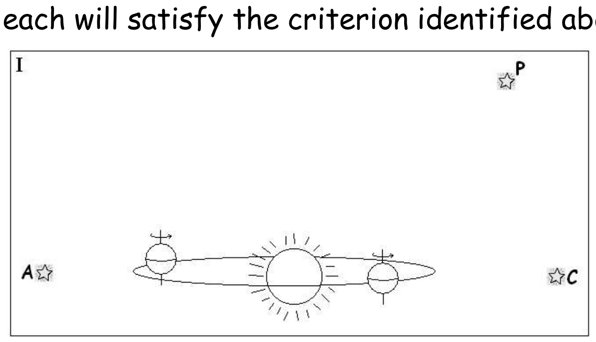
3) Rotate the earth around so that X is in position B, C, and D in the diagram above.
   What time of day is it for the people at locations B (sunset)
   C (midnight)
   D (sunrise)

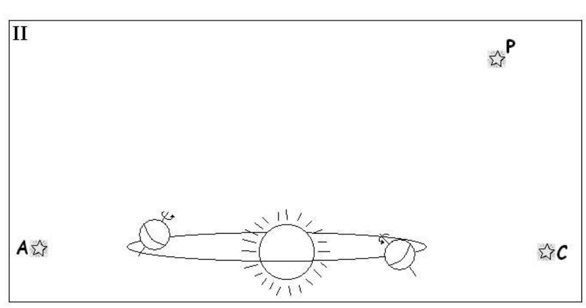
4) Put a person figure at all four positions (A, B, C, D) if needed for them to answer this
   Is the time of day the same for all locations on the earth at the same moment? (No)

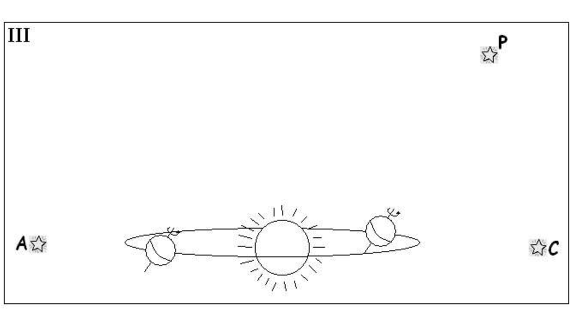
5) a) What determines "time of day?" (your location on the earth relative to the sun)
   b) What is a "day" in terms of the rotation of the Earth? (one complete rotation)

II <u>Orientation of the Earth's Rotation Axis Activity</u>:
1) If the north star (Polaris, "P") always appears directly overhead at the north pole, which of the following represents how the earth is oriented throughout the year as it orbits the sun?

You should act out each of the following scenarios and have the students ascertain whether each will satisfy the criterion identified above.







Appendix D

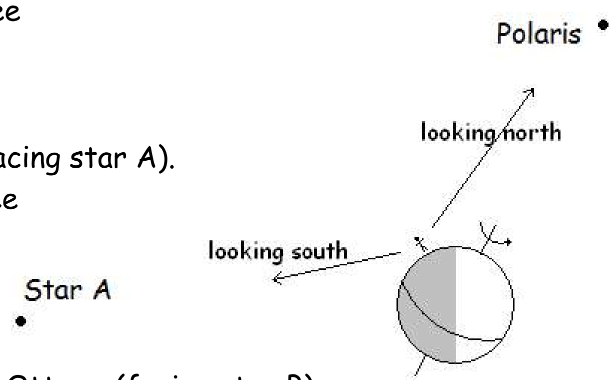
III) <u>Star Motion Activity</u>: apparent motion through the night

1) How do the stars appear to move in the sky over the course of a night?
Place the model earth between the sun and star A.
Its rotation axis should be tilted towards star C - pointing towards star P.

a) At what time of day does it start to become possible to see stars in the sky?
Have them rotate the earth until Ottawa is at that time of day.
(in position B from the previous diagram; facing star D)

b) What direction does the figure have to look to see
Star D? (straight up - i.e., near the Zenith)
Star A? (eastern horizon)

c) Rotate the earth until it is midnight in Ottawa (facing star A).
What direction does the figure have to look to see
Star D? (western horizon)
Star A? (up and to the south - not straight up)
Star B? (eastern horizon)



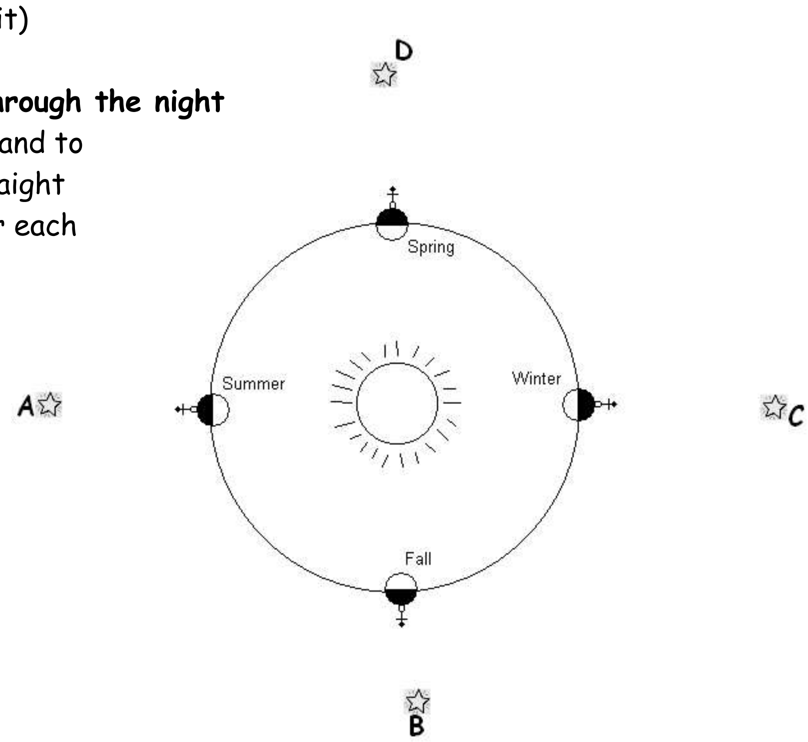
d) Rotate the earth until it is just before sunrise in Ottawa (facing star B).
What direction does the figure have to look to see
Star B? (straight up - i.e., near the Zenith)
Star A? (western horizon)

2) Rotate the earth model through the last 3 positions.
In what direction does the person figure need to look to see Polaris (North in each case)

3) Sum up: How do stars appear to move across the sky over the course of a night?
(rise at eastern horizon, rise high into the sky, the set below western horizon)
Do the stars actually move in this way?
(no, the earth is rotating)
Why are we unlikely to see star C at this time of year?
(we have to look near the sun to see it)

III) <u>Star Motion Activity</u>: apparent motion through the night

1) In the northern hemisphere, when we look up and to the south at midnight, we are looking mostly straight out, away from the sun. This is the situation for each of the stick figures in the diagram to the right.



Have the students figure out which of each of the four labeled stars is visible and where it is in the sky at midnight for each of the four seasons?

a) Summer (already done)
East: (B) South: (A) West: (D)

b) Fall
East: (C) South: (B) West: (A)

c) Winter
East: (D) South: (C) West: (B)

d) Spring
East: (A) South: (D) West: (C)

<u>Summary</u>

15) a) If you look to the southern half of the sky each night at the same time each night over several months, how would the stars appear to shift position over this time? (E>up>W)

b) How does this compare to the hourly changes in position over a night? (same)

c) If you wanted to see what the stars will look like next month at midnight, how can you do this? (go outside about an hour and a half later during this night)

Appendix D

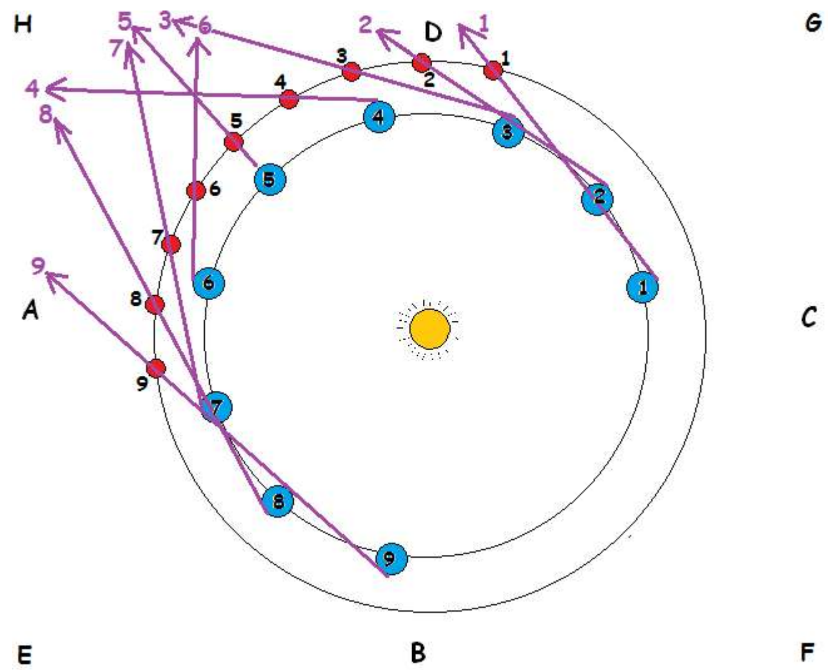
IV) Planetary Motion Activity

Set up the model solar system to match position 1 in the diagram below:

the earth is between the sun and star C

the smaller balloon (Mars) is farther from the sun and just to the "C" side of D

You will have to remind them that planets rarely line up in their orbits around the sun. This is because their orbits are of different lengths (longer is farther out) and they orbit at different speeds (slower farther out).



1) Ask them why the orbital speed should decrease the farther a planet is from the sun.
   What holds the planets in orbit around the sun? (gravity)
   How do the planets avoid falling into the sun (previous eep lesson: move sideways)
   What happens to its strength of gravity as one moves farther from the sun? (weaker)
   How fast must the planets move sideways to stay in orbit as they get father from the sun? (slower, since solar gravity is weaker)

So, we are starting out our process with mars and the earth not lined up going out from the sun.

Hour-to-hour apparent motion of mars:

2) Have them rotate the earth from midnight to sunrise.
   How will mars seem to move across the sky? (same as stars, from east to west)

Day-to-day apparent motion of mars (viewed at midnight):

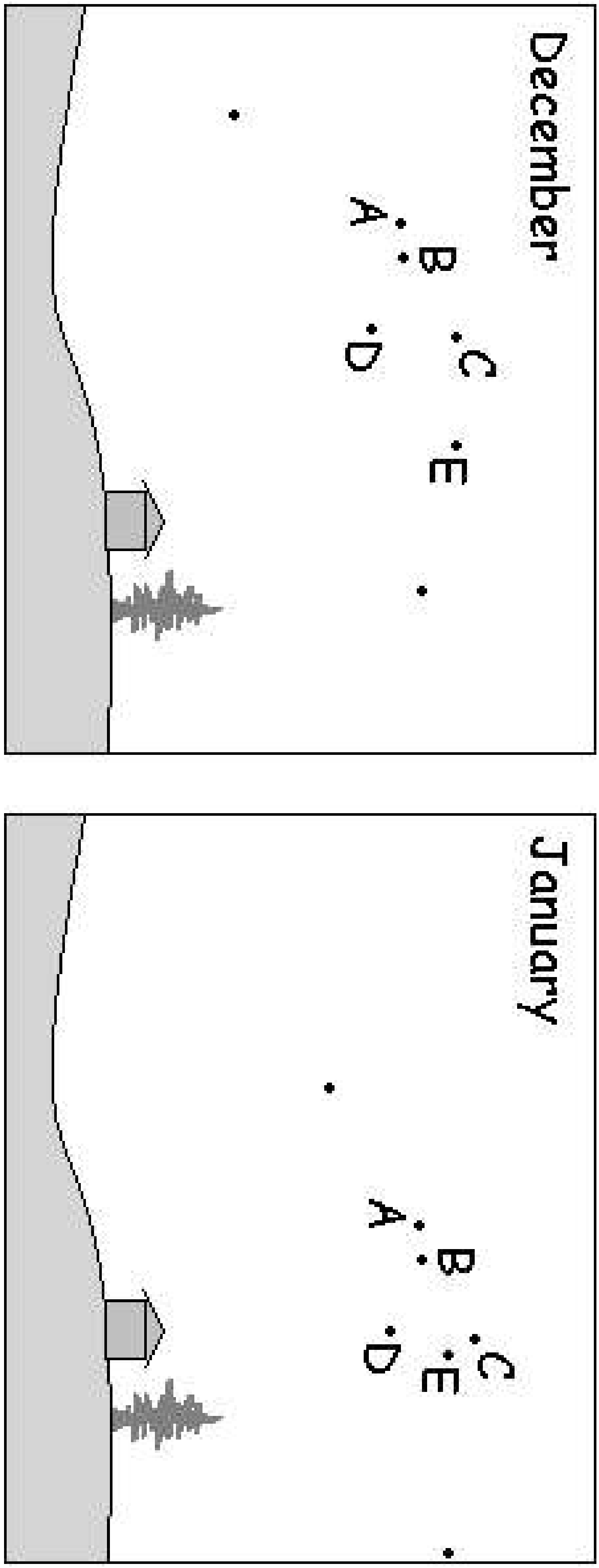
3) Most of the time.
   a) Have the students move the planets from positions 1 to 2, to 3, and to 4. In each position, have the students describe the apparent position of mars relative to the fixed stars (D, H, and A) (just west of D, just east of D, between H and D, just east of H) and in the sky (at east horizon and rising higher above east horizon at each position).
   b) Summarize the pattern of apparent motion. (progresses from east to west, but much less fast than the stars; resulting in a motion from west to east relative to the stars)
   c) Ask them why the planet's motion in the sky is different from that of the stars. (Mars also is orbiting the sun, unlike the stars)

   When earth passes mars in its orbit.

   d) Repeat the observations at positions 5 and 6 (mars seems to move from east to west relative to the stars: back towards star D; opposite to the normal direction)
   e) Repeat the observations at positions 7, 8, and 9. (Mars is back to moving eastward relative to the background stars).

Appendix D

4) Which of the objects in the picture is a planet?



V) <u>Summer versus winter</u>

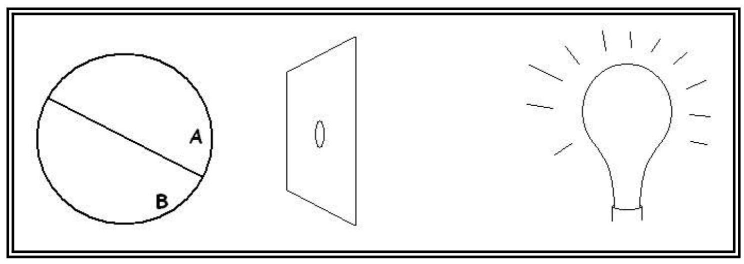
The earth's orbit around the sun is not a perfect circle. It is about 5 million kilometres closer at its closest than at its farthest. This difference is about 3% of the average distance.

1) Question: is this enough to cause the difference between summer and winter?

(consider that the winter to summer temperature range is 15% of the average)
(also consider that when it is summer for us, it is winter in the southern hemisphere and the difference in distance from the sun is a few hundred kilometres)

2) An alternate hypothesis:

Place the model earth a couple of metres from the sun lamp in the summer location (rotation axis tilted towards the sun). Make sure that the Ottawa location is at the same height above the floor as the sun light bulb. The card always is held vertically, so the hole always lets the same amount of light energy pass through it.



a) Place the card so that the circle cutout shines light onto the location of Ottawa (A).
b) Estimate the area of the of the light spot on the surface of the earth.
c) Move the earth upward until the light spot falls on location "B" - a spot the same distance below the equator as Ottawa is above it.
d) Estimate the area of light spot. (it should be much more spread out).
e) Why is it winter in the south at this time? (the same amount of light energy is spread out over a much larger area, so each unit of area gets less sunlight energy than the same unit of area at Ottawa).

3) From what they have learned, what circumstances will cause it to be summer in the southern hemisphere? Have them test their ideas with the model. (They should discover that when the earth model is in the southern hemisphere, the card with the hole it in will cause a smaller light spot.

Appendix D

VI) Moon Phases

1) Reiterate that time of day is nothing more than the direction your part of the Earth is facing relative to the sun. The Earth rotates counter-clockwise.

New information: the moon orbits the earth (actually they both orbit their common center of mass, which is inside the earth, but not at its centre).

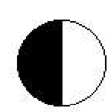
2) Set up the model solar system to match the following diagram. The small balloon that was used for mars previously is used to represent the moon.

The earth balloon can be rotated as needed to put the masking tape person model into the three different times of day on the diagram. Start out with the person in position B.

The lamp for the sun should be on, if possible. If not, colour one side of the moon balloon and keep this side facing the sun lamp.

In this simulation, it is particularly useful to have a student record the visual results of the simulation.

You can simplify this simulation by keeping the earth's orbit axis vertical, but this is not necessary.
The moon's orbit around the earth is at a slight angle to the earth's orbit around the sun. Account for this by shifting the moon down enough on the far side of the earth from the sun so that it is not in earth's shadow and up enough on the near side to the sun so that earth is not in the moon's shadow. The shadows (eclipses) do occur, but not on each orbit. The moon must be close to an orbital node (half-way between the high and low points of the orbit) for an eclipse to occur (see below)



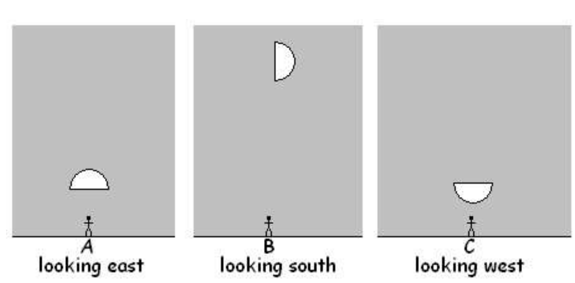
3) From position B:
a) What time of day is it for the person? (sunset)
b) What shape will the moon display in the sky?
c) Is it illuminated on the left or right side? (right)
d) In what direction does a person have to look to see it in the sky? (south)
e) How high is it above the horizon? (very high)

4) What do we mean by "shape of the moon?" (how much of the face is illuminated and, therefore, visible to us we call this the moon's "phase")

5) Rotate the earth so that the person is at position A on the big diagram above.
Rotate the figure so that it is facing the moon. (it needs to be facing east)
Have students put their faces in close to the person figure so that they can see what the figure would see.
a) What time of day is it for the person? (noon)
b) Is the moon visible to the figure? If so, where is it in the sky? (yes; eastern horizon)
c) Does the moon have the same phase? (yes, half the face is visible)
d) Does it have the same orientation? (no, it is flat-side down rather than to the left)

6) Rotate the earth so that the person is in position C for the large diagram above.
Answer the same 4 questions as for part 5 above.
The answers are: midnight; yes, western horizon; yes; and no, flat-side up.

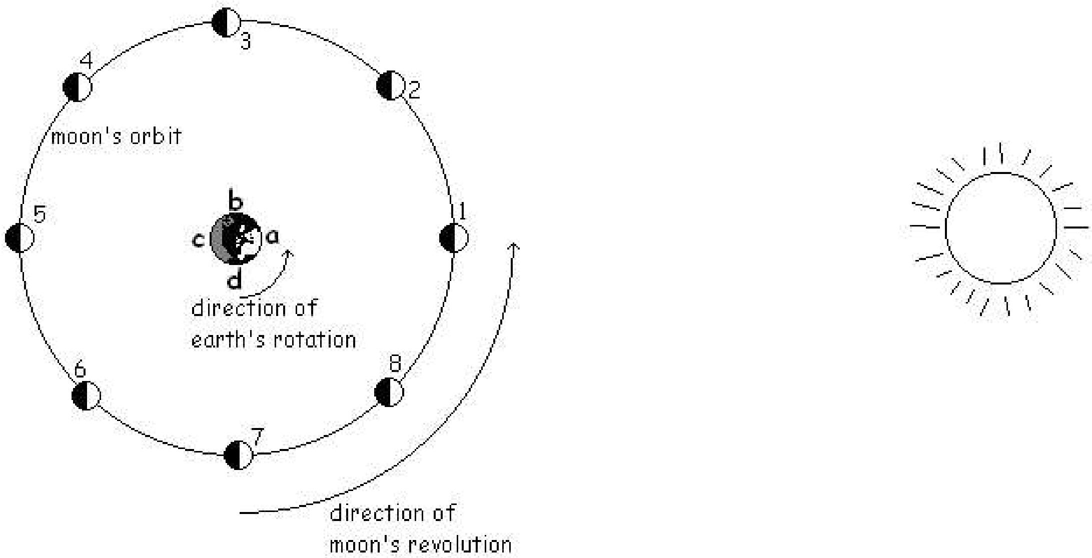
Summary of results for parts 4, 5, and 6:



7) Does the change in the moon's orientation have something to do with the moon itself?
(No, it is a result of the fact that we are rotating around on the earth to look at it.)

8) Is the moon visible to a person at sunrise (D)? (No)

9) We will now investigate the effect of the moon's position in its orbit relative to the sun on its phase.

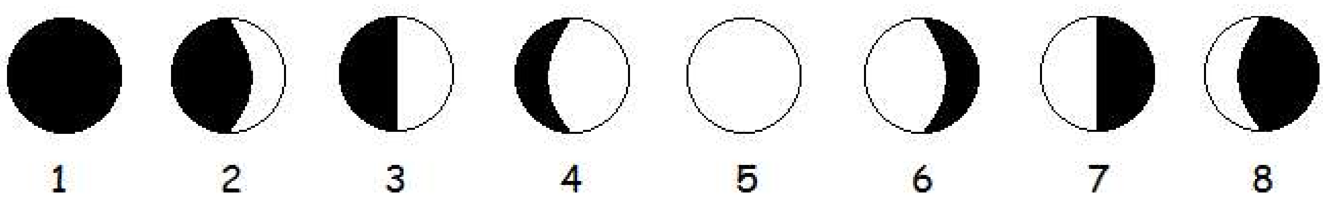


Set the moon to each of the locations 1 to 8 shown in the diagram to the right.

At each position, rotate the earth so that the moon is highest in the sky.

The students should be able to identify
- a) the phase shape
- b) the time of day that the moon is highest in the sky

These are the phases that they should see (they should be sketched on the board):
It is important that they view the moon as it would be seen by the figure. Stand behind the earth and look in the same direction as the figure. This is so they see the correct left-right orientation of the phase.



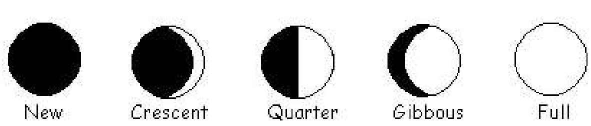
noon	3 PM	6 PM	9 PM	midnight	3 AM	6 AM	9 AM

Teach them the following definitions: waxing moon - the illuminated side is getting larger each night
waning moon - the illuminated side is getting smaller each night

10) Which moons are waxing (2,3,4) and which are waning (6,7,8)?

11) What do the waxing and waning moons have in common? (waxing moons are illuminated on the right)
(waning moons are illuminated on the left)

12) Moon phase names.
Describe the names and have the students label their sketches. Except for full and new moons, the phase name must be modified as to whether it is waxing or waning.



Appendix D

6) Grade 9 Planetarium Presentation

Time: 30-45 minutes total time inside the dome

Set Up

1) Load the constellations cylinder.
2) Set tilt on lamp to match Ottawa's latitude: about 45 degrees.
3) Orient projector so that Polaris is pointing in the direction that you have decided that north is.
4) Rotate the cylinder to show the sky at 10 PM on or about the current date.

   e.g., for March, the Cepheus should be upright with the peak of the "roof" pointing up.
   to the south, Gemini should be close to directly south.

   This will be your reference view for most of the presentation.

   For typical times of year for our presentations, there are diagrams in figure 1 showing the location of stars so that the planetarium cylinder can be properly oriented.

While dome is re-inflating and before fan is switched to low power setting

5) Get the students seated.
6) gradually turn down the side lamps and leave the projector lamp on a low setting.

As their eyes are adjusting, go over the parts of the sky:

a) show them where north is
   ask the name of student that is at the north position of the dome
b) show them where south, east, and west are (west and east spell out"we" if you are facing north).
c) ask them if they know what the top of the sky is called (the point directly over your head);
   make sure that everyone knows it is called the "zenith"
d) ask them the name for the line where the earth and the sky meet (horizon), hopefully they all know it.
e) ask them what a star is.
   ask them how they are related to the sun.
f) ask them what a constellation is and who named them: the names that we use are Greek in origin.
   Most star names in use today are based on names given by Arabic cultures.

Constellations Cylinder

7) Describe what they are seeing: the major stars only with lines showing the formal constellations
   These are the shapes that the ancient Greeks saw when they looked up at the sky.

8) Point out the asterisms big and little dippers and the star Polaris.

Ask them what is special about Polaris:

a) Polaris is exactly above the earth's north pole.
   this is why Polaris is always to the north.
b) verify this by slowly spinning the cylinder (careful, serious regurgitation is possible) while
   keeping the light pointer on Polaris.

If you have younger students only, you can skip to step 11

c) point out the line marking the equator and the ecliptic (the plane of the solar system).
   they are not the same lines because the earth's rotation axis is tilted about 23 degrees relative to the rotation plane of the solar system

d) Ask them what the stars would appear to do as the earth spins on its axis.
   If you need to, point out that the earth spins counter clock-wise (when viewed from the north) (west to east, that is)
   Conclude, that like the sun, the stars will rise in the east move across the sky and set in the west
   They move counter-clockwise if looking north, clockwise if looking south.
   Demonstrate by slowly spinning the cylinder in a clock-wise direction.

9) a) What would the sky look like if we were lying on the ground looking upward while at the north pole?
   Tilt the cylinder so that polaris is at the Zenith.
   b) Ask them what the stars will appear to do in the sky as the earth rotates.
   Demonstrate by spinning the cylinder clock-wise.
   Point out that polaris does not appear to move much. (keep your light pointer on it)
   The stars rotate around parallel to the horizon: nothing rises and sets, things just spin around.
   c) What would the sky look like if we were at the equator.
   Tilt the cylinder so that polaris is at the horizon.
   Ask them what the stars would appear to do in the sky as the
   Demonstrate by spinning the cylinder clock-wise.

   Ask them if we could see polaris if we were south of the equator.
   Conclude that we could not, since it would be below the horizon; blocked by the earth.

10) Turn out the lamp, re-tilt the cylinder for a 45 degrees latitude, turn the lamp back on
Point out that since we are about half way between the equator and the north pole, that polaris is about half way between the Zenith and the horizon.

a) the sun, moon, and planets move along this line.
The all rotate from east to west with the stars as the earth turns, but each of the solar system objects is a little farther west along this line on each successive night
the moon moves the greatest amount in this way,
the planets move less the more distant they are

11) a) <u>Go over the major ***North-Sky*** constellations and asterisms and how to find them</u>
Start with the **big dipper**
Show how to use the pointer stars to find the **little dipper**, **Cassiopeia**, **Cepheus**, **Cygnus**, and **Draco**.

b) Show how to measure angles with you fist (10 degrees) and finger (1 degree) at arms length.

c) imagine pouring water out of the cup of the big dipper.
follow the line of the pointer stars in that direction
polaris is about 30 degrees from the near pointer star, or about three fists
d) Cepheus is about 1.5 to 2 more fists past polaris
e) Take a 90 degrees right turn at Cepheus, Cassiopeia is 1.5 fists in that direction.
f) Draco's tail starts half way between the cups of the little and big dipper. Draco curls around the cup of polaris back towards Cepheus and then doubles back on itself towards its pointy head.

g) Talk about how Cepheus looks like he has a really big (swelled) square head and a party hat rather than a crown, since kings like to party a lot. Talk about how Cassiopeia looks like a person sitting on a throne, but with really big feet. She is facing Cepheus, ready to give him a good kick with her big feet when he gets too wild with his partying.

h) You can point out some other constellations like Cygnus, Lyra, and Bootes.
Cygnus, the swan. The bright star forming the tail of the swan can be found by following a line from Polaris just behind the head of Cepheus (the side away from Cassiopeia) about 2 fists past the base of Cepheus' skull. You can easily see the bright star Deneb near the between Cygnus' wings.
Lyra, a small kite-like constellation just one fist off of Draco's nose. The bright star is Vega.
Bootes, the herdsman (ice cream cone). Follow the arc of the handle of the big dipper for twice more its length.

12) a) <u>Go over the major ***South-Sky*** constellations and asterisms and how to find them</u>
The previous constellations can be seen at any time of year. The southern constellations change from season to season. This is because we only can see stars when out part of the earth is facing away from the sun. However, because the earth revolves around the sun, we are facing a different direction when the earth rotates around so that our location is on the far side from the sun in each different season.
b) To face the opposite direction at night, we can use one of the northern constellations to guide us:
September: trace a line from Polaris up and through Cepheus
December: extend the line of the handle of the little dipper
May: trace a line through the pointer stars of the big dipper in the direction opposite Polaris

c) We should show them:
Leo: (backwards question mark found by following the big dipper pointer stars away from Polaris),
Orion: (follow the handle of the little dipper up and over to the south)
figure-8 shape
Canis Major: follow Orion's belt down to the left
Taurus: V-shape found by following Orion's belt up to the right
Gemini: box shape half-way between Taurus and Leo

13) Give them some practice by either pointing to constellations at random or by passing around the pointer and asking them to point to constellations. You can decide which based on how much time you have and how the class behaves.

14) Put up the star field cylinder. Talk about light pollution and how it affects the ability to see stars.
a) Do this by adjusting the side lamps.

side lamps on low illumination:	city viewing conditions the "sky" seems a bit grey and only the brighter stars show up this can make it easier to spot the major constellations
side lamps off:	country viewing conditions with no light pollution, you can see about 3000 stars.

Depending on how confident they seem, you can go over the same techniques that you used with the constellation cylinder.

b) First: have everyone search for the big dipper. Most should find it.

c) - go over the same techniques with them that you did with the constellation cylinder
- have a little quiz where you point and ask the to call out what constellation it is.
- have them close their eyes, or turn off the projector lamp, and rotate/tilt the cylinder then turn the projector back on and see how fast they can find the big dipper.

d) Go back to today's orientation and pass the light pointer around.

15) Show them the following stars:

Betelgeuse (beetle juice)

right shoulder of Orion, 400 LY away (what does that mean?)
name modified from the original arabic name that meant "armpit of the great one."
ask them the colour: they should agree that it is red in colour:
tell them that it is very large, 1000 times bigger than the sun.
- if it was our sun, even Mars would be inside the sun

Rigel

left knee of Orion, 800 LY away
ask them the colour: they should agree that it is blue in colour
a large star, but not as large as Betelgeuse (about 75 time the size of the sun)
tell them that it is about 10,000 times more luminous than the sun

Sirius

bright star on the collar of Canis Major
about 8 LY away
ask them the colour: they should agree that it is whitish yellow
tell them that it is about the same size as the sun
the second brightest star in the sky (ask what is the brightest, the correct answer is the sun)

Discuss the following with them (try eliciting opinions first)

a) What do the different colours mean (red=cool (3000 °C), yellow= warm (6000 °C), blue=hot (25000 °C))

b) All three stars look equally bright,
but if Rigel and Betelgeuse are much more luminous than the sun
while Sirius is about as bright as our sun
what does their similar brightness mean?

Point out that brightness is a measure of how the star looks to our eyes
luminosity is a measure of how much light energy is given off per second (power).

They should be able to figure out that Rigel and Betelgeuse are very far away while Sirius is close by. Thus, the reason Rigel is so luminous and yet is just a bit less bright that Sirius, is because it is so far away - like a small flashlight close by and a powerful search light very far away can see the same brightness.

Brightness is proportional to luminosity over distance squared.

If Rigel is about the same brightness, but is 100 times farther away (800 LY vs 8 LY), then to seem about as bright as Sirius, it must be 10,000 times more luminous, since a distance of 100 time more squared is 10,000

That should get you to the end of the presentation.

Appendix D

Reference Material

Orion is the most obvious constellation in this direction. Show them Orion's belt, two shoulders, knees (skirt), right arm picking out an arrow, and left arm with bow ready to shoot.
Orion's two dogs, **Canis Major** (under the right arm and below Orion's knees) and **Canis Minor** (follow the line from the left shoulder star through the right shoulder star and go about two fists in that direction).
Taurus, the bull (running from Orion), just above Orion's bow (a triangle of stars forms the head)
Gemini, the twins, a mirror image pair of constellations like two people with their arms out in front standing back-to-back. They are just off of Orion's right arm in a direction perpendicular to the upper arm.
Leo, the lion (looks more like a horse). Follow a line from Orion between Gemini and Canis Minor about 6 fists or so. It looks as if it is running after Orion (the hunter is being hunted).
Half-way between Taurus and Cassiopeia is **Perseus**, the hero. He looks like a person leaning forward with one arm curving up behind his back (well, sort of).
Perseus rescued (almost) his girl friend **Andromeda** (Daughter of Cassiopeia and Cepheus) from Hades (Hell). Andromeda looks like a big, upper-case "A" with the base of the "A" half way between Perseus and Cassiopeia. The "A" is pointing in the direction away from the big dipper.

Rotate the cylinder so that it is early evening (Orion is on the eastern horizon)
Cygnus, the swan. The bright star forming the tail of the swan can be found by following a line from Polaris just behind the head of Cepheus (the side away from Cassiopeia) about 2 fists past the base of Cepheus' skull.
Lyra, a small kite-like constellation just one fist off of Draco's nose. The bright star is Vega.
Bootes, the herdsman (ice cream cone). Follow the arc of the handle of the big dipper for twice more its length to find Arcturus at the base of Bootes.
Virgo, the maiden can be found by following the arc of the dipper's handle another two lengths to find Spica.
Scorpio, follow the tail of Cygnus for twice Cygnus's length to get to Antares
Sagittarius, the archer (the tea pot) just to the left of the tail of Scorpio.

<u>Have the students practice identifying the constellations</u>
<u>Star Motion</u>
Show that Orion will be at the eastern horizon at sun-set. It will rise up into the southern sky and will be chased by Leo which rises when Orion is high in the sky. By 4 AM, when they are just finishing their home work, Orion will have set, and Leo will be high in the sky.
The stars near the equator move about 1.5 fists across the sky per hour.
Demonstrate by rotating the cylinder.

As the earth revolves around the sun the stars positions, at a given time of night, also will shift. They move about 3 fists per month, from the east to the west, or about as far as they move in two hours on a given night. So, Orion at midnight on February 1st is in the same position that it was at 10 PM on January 1st.
Demonstrate by rotating the cylinder.

For constellations near the horizon, we can only see them at certain times of year. Winter constellations, like Orion, not visible in the summer because they rise during the day and set before it is dark enough in the evening. In order to see a constellation, your part of the earth must be facing it at night, not during the day.

<u>Change cylinders to the urban star field</u>
Rotate the cylinder so Orion is due south again.
Briefly explain that city lights wash out the light from the fainter stars. They make the sky brighter, and only the stars that are brighter than the sky can be seen.
Point out that this can make the constellations easier to pick out.

<u>Have students pick out the major constellations</u>
Pass the light pointer around to different students.
Talk them through the same set of directions as explained previously.
Try the same process after all have been found with the sky rotated to a new time of night.

Appendix D

Change cylinders to the dark-sky star field
Ask the students how many stars they think that they can see.
Ask them if they could count them all; conclude that you could not
Ask them how could the number be estimated.
    Conclude that you could count a small patch
    multiply be how many time the patch would fit in to the whole sky
Try out the method.
    Turn on the reading lamp just a bit
    Hold hands at arms length with the thumbs and index fingers making a square
        should get about 15-20 stars in this space
        should estimate that the patch could fit into the sky about 200 times
        yields an estimate of 3000-4000 stars
All these stars are in our own galaxy, and fairly close to us (less than a few thousand LY)
    (1 LY is the distance light travels in one year (300,000 km/sec for 1 year = 10 trillion km)
    (the galaxy is about 100,000 LY across) If the galaxy was drawn on a standard sheet of paper, most of the stars that we see would be contained in an area less than 5 mm across.

For comparison:
    if stars were grains of sand, all 3000 that we can see would fit in a thimble
    if all the stars in the universe were grains of sand, they would amount to more sand than all the beaches on the earth; if put in rail-road box-cars, the train would be so long, it would take more than three years to travel past a rail-road crossing.

Point out some of the major stars
Betelgeuse (beetle juice)
    right shoulder of Orion, 400 LY away
    name modified from the original arabic name that meant "armpit of the great one."
    red colour: very cool, just over half the temperature of the sun
    very large, 1000 times bigger than the sun. If it was our sun, even Mars would be inside the sun

Rigel
    left knee of Orion, 800 LY away
    blue colour: very hot; more than twice as hot as the sun
    a large star, but not as large as Betelgeuse (about 75 time the size of the sun)
    is twice as far away as Betelgeuse but seems brighter in the sky because it is more luminous
    it is about 10,000 times more luminous than the sun

Sirius
    bright star on the collar of Canis Major
    whitish yellow (slightly hotter than the sun)
    about the same size as the sun (1.5 times bigger)
    the second brightest star in the sky (ask what is the brightest, the correct answer is the sun)
    it is much less luminous than Rigel or Betelgeuse (25 times more luminous than the sun)
    seems brighter, however, because it is much closer 8.5 LY
        the light we see from Sirius today actually left the star when the students entered grade 1
        explain   brightness: how bright a star appears to us
                   luminosity: how much light energy the star actually releases

    Sirius has a companion star that orbits it like a planet (Sirius B), but it is too faint to see
        is a white dwarf, a star that has collapsed after its fuel has run out
        is about the same size as the earth, but with a mass similar to that of the sun - very dense

Most solar systems have more than one star - single star solar systems like ours are less common

Capella
    the bright star in Auriga, the charioteer, (above Orion and to the back side of Perseus)
    is the brightest star in a solar system that has at least 10 known suns

Algol - the demon
    the bright star near the foot of Perseus' forward leg (the one towards Andromeda)
    consists of a pair of stars - one much dimmer than the other
    every 2 days and 21 hours the dimmer star passes right between us and the brighter star
        over a four-hour period, you can see Algol dim to about a tenth its normal brightness

Procyon
    The bright star in Canis minor; it is very similar to our sun, about 11 LY away

Appendix D

Regulus

Bright star in Leo, 79 LY away.

Show this to a grandparent on their 79th birthday. Tell them that they light that they are seeing now left the star the year that they were born and for all their life and during all the things that they have done, the light that they are seeing now has been traveling through space towards them.

It is an odd star, being a blue (hot) dwarf star

Castor and **Pollux**

bright stars forming the heads of the twins in Gemini

Pollux is the brighter star, closer to the horizon

Pollux is an orange giant star - cooler than the sun, hotter and smaller than red Betelgeuse

Pollux is about 35 LY from us

Aldebaran

the bright "eye" in the head of Taurus, the bull

another orange giant star, 68 light years away

it is only half the distance away as all the other stars in the head of Taurus.

the stars in most constellations do not actually form real groups in space

they only appear close together when viewed from earth because they are in the same direction

E.G. Wezen, a bright super-giant star that forms the bum of Canis Major, is over 1800 LY from earth. It is very dim compared to Sirius, in the same constellation, which is only 8.5 LY away.

The **Pleiades** star cluster is an example of a real group of stars close together in space.

Deneb

Name means "tail" in arabic - it is the tail of Cygnus

One of the most luminous of all stars that we can see

only the 13 most bright since it is 3000 LY away

if it was as close as Pollux, it would be as bright as the moon

Vega

the bright star in Lyra

Ask the students if they have ever seen a spinning top.

Ask if it they stay in one orientation or if the spin axis wobbles. They wobble.

Point out that the earth is like a spinning top, and it wobbles too, though much slower.

Right now, the earth's spin axis points to Polaris.

In 12,000 years, the earth's spin axis will point very near Vega, which will be the north star.

Back when the pyramids were being built, the north star was the second star from the end of Draco's tail.

Arcturus

The bright star at the base of Bootes.

A orange giant star only 37 LY from earth.

Antares

The bright star at the back of the head of Scorpio.

A very bright red super giant like Betelgeuse

Spica

A hot blue star in the middle of Virgo.

<u>Practice Identifying Stars and Constellations</u>

At this point, you will probably have about 5 minutes or so left.

Spend it giving the students the pointer light and having them find specific stars and constellations.

If you have time left over, you can point out the following objects

<u>Time fillers</u>

Most stars have Arabic names, while the constellations have mostly Greek names.

Merak and Debhe are the pointers in the big dipper (Dubhe is the closer to Polaris)

Bellatrix is the right shoulder of Orion, while Saiph is the left knee

Many stars have no names, just letter designations based on the constellation that they are in.

Cygnus-X1 is a star about half-way along the neck of the Cygnus, the swan. It orbits a blue supergiant star and is the first star that was identified as being a black hole - a star so small and massive that not even light can escape its gravity.

Not all the objects in the sky are stars. The sword of Orion, hanging from his belt, is made up of three bright points. Only the lowest is a star. The middle point is the great nebula of Orion, a vast cloud of dust and gas bigger than several solar systems. From our distance of 1300 LY, it looks like a star, unless you use a telescope. Orion "contains" several other nebulas, the upper point of the sword and the horse-head nebula beside Barnard's star on the belt (one of the closest stars, 6 LY).

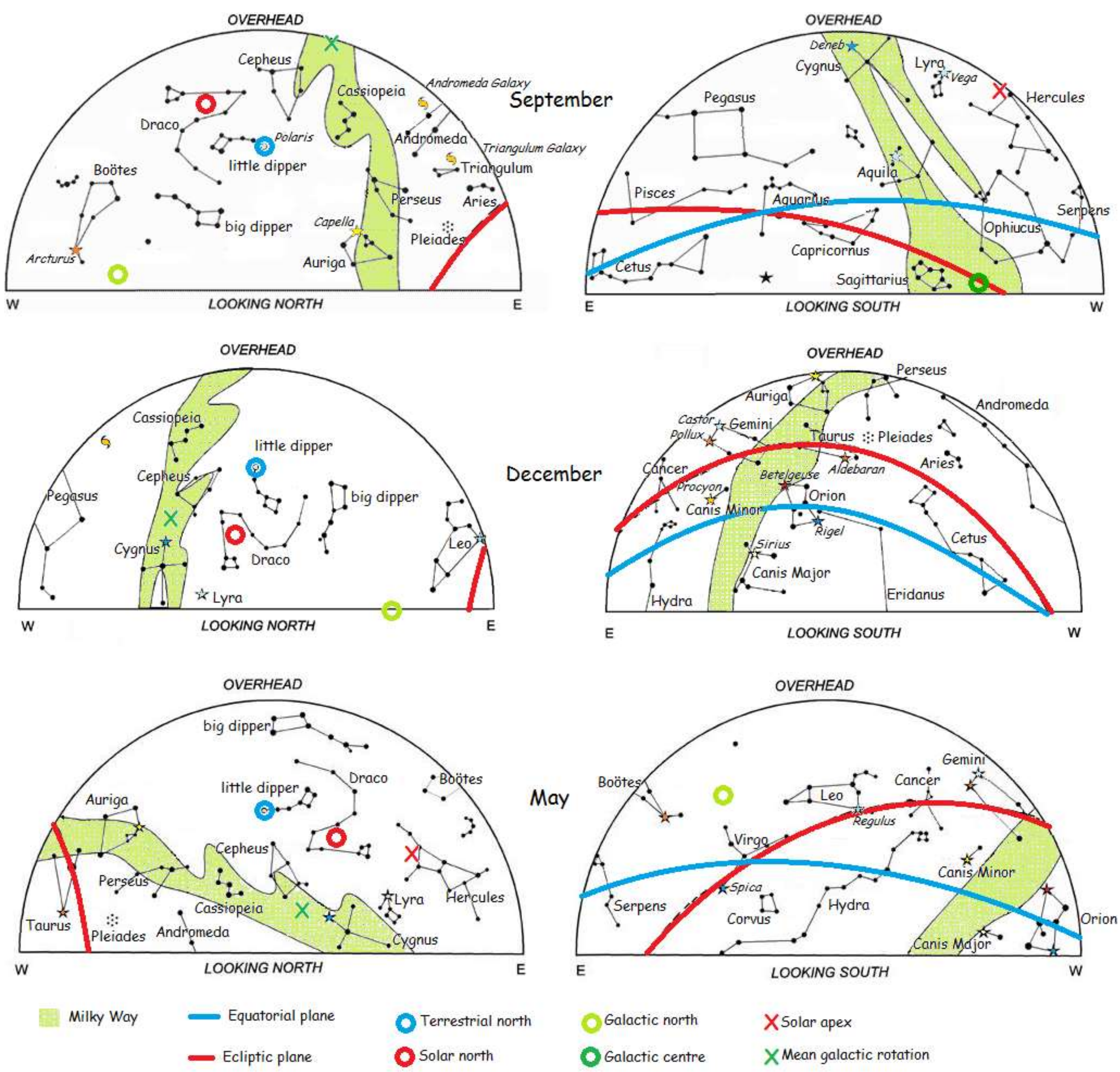
Appendix D

The most distant object that can be seen with the naked eye is another galaxy - the Andromeda Galaxy, about 2,000,000 LY from our galaxy. The two stars that form the cross bar of the "A" in the Andromeda constellation (Mirach and Mu) form convenient pointers to the Andromeda galaxy. Follow the line from Mirach to Mu (roughly towards Cepheus) for a distance roughly the same as that between Mirach and Mu. The faint smudge there is the Andromeda Galaxy, a spiral galaxy like our own, but twice as large.

Our own galaxy shows up as a faint hazy band (it looks like a band of spilled milk) across the sky from Cygnus through Cassiopeia, Perseus, and Orion's right arm and between Orion's two dogs. It is not shown on our star-field cylinders

The ecliptic, which goes through Leo, Gemini, and Taurus. The solar system is tilted by 65 degrees relative to the disk of our galaxy. The boundary between Gemini and Taurus points directly away from the centre of the galaxy. The eastern edge of Sagittarius, not visible in the winter, points towards the center of our galaxy. Coma Berenices points directly out from the surface of the galactic disk. Deneb points roughly in the average direction that our part of the galaxy is moving as it orbits the galactic centre. Our solar system is moving towards the boundary between Hercules and Lyra. This is termed the ***solar apex***. Our solar system follows a roughly sinusoidal path around the galaxy, passing above then below the disk of the galaxy several times in each orbit.

Figure 1.



APPENDIX E: CURRICULUM EXPECTATIONS RELEVANT TO THE OCESS PROGRAM

<table>
<tr><td colspan="4">Course</td></tr>
<tr><td colspan="4">Strand</td></tr>
<tr><td rowspan="2">Overall Expectation</td><td colspan="3">Description of overall expectation</td></tr>
<tr><td>Specific Expectation</td><td>Description of specific expectation</td><td>Spacesim activities that address the specific expectation</td></tr>
</table>

<table>
<tr><td colspan="4">Grade 9 Science SNC1D</td></tr>
<tr><td colspan="4">A: SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION</td></tr>
<tr><td rowspan="13">A1</td><td colspan="2">Demonstrate scientific investigation skills in:
initiating and planning,
performing and recording,
analysing and interpreting, and
communicating;</td><td rowspan="13">Students select a mission destination each year. This selection is justified in part on a set of mission goals and experiments to be carried out based on those goals.

The overall goals must address some current issue in space science or technology or an issue that could conceivably be relevant in the near future.

Students are guided in this process by:
- the teacher advisor
- past members
- affiliate organizations (LTS, PS, CSS)
- student research

With guidance, students devise a set of investigations to address the mission goals. These investigations include specific experiments.

Individual students and small groups of students take responsibility for specific experiments. Each experiment design must include a procedure, lists of materials and equipment needed, the type and quantity of data needed, and an outline of the analytical procedures required.

The teacher advisor, past members, and other advisors determine how the analogue data will be generated, which procedures can be carried out in a real sense and which must be simulated.

The advisors and student members of the simulator task force then determine how the analogue planetary destination will be constructed so as to allow for the collection of the appropriate samples and data.

Experimental procedures are integrated into the mission time line.

Data collection takes place during the mission and includes measurements and other observations on the planetary surface and in the computer simulated environment. Samples and data must be appropriately catalogued and recorded. Some data analysis takes place during the mission. Analysis is completed during work sessions after the mission has been completed.

Once each experiment's analyses are complete, a report is written up. These reports are integrated into a mission report.</td></tr>
<tr><td>A1.01</td><td>Formulate scientific questions about observed relationships, ideas, problems, and/or issues;

Make predictions, and/or formulate hypotheses to focus inquiries or research</td></tr>
<tr><td>A1.02</td><td>Select appropriate instruments and materials for particular inquiries</td></tr>
<tr><td>A1.03</td><td>Identify and locate print, electronic, and human sources that are relevant to research questions</td></tr>
<tr><td>A1.04</td><td>Apply knowledge and understanding of safe practices and procedures when planning investigations.</td></tr>
<tr><td>A1.05</td><td>Conduct inquiries, controlling some variables, adapting or extending procedures as required, using standard equipment and materials safely, accurately, and effectively, to collect data</td></tr>
<tr><td>A1.06</td><td>Gather data from laboratory and other sources; organize and record the data using appropriate formats</td></tr>
<tr><td>A1.08</td><td>Analyse and interpret qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis, identifying possible sources of error, bias, or uncertainty</td></tr>
<tr><td>A1.09</td><td>Analyse the information gathered from research sources for reliability and bias</td></tr>
<tr><td>A1.10</td><td>Draw conclusions based on inquiry results and research findings, and justify their conclusions</td></tr>
<tr><td>A1.11</td><td>Communicate ideas, plans, procedures, results, and conclusions orally and in writing</td></tr>
<tr><td>A1.12</td><td>Use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units</td></tr>
<tr><td>A1.13</td><td>Express the results of any calculations involving data accurately and precisely</td></tr>
<tr><td rowspan="2">A2</td><td colspan="2">Identify and describe a variety of careers related to the fields of science under study and identify scientists, including Canadians, who have made contributions to those fields.</td><td rowspan="2">Student members participate in training and mission preparation activities in the same way as NASA and CSA astronauts, mission control staff, and mission back-up team members. Experiment design and research activities give students experience in the day-to-day work of space science research.</td></tr>
<tr><td>A2.1</td><td>Identify and describe a variety of careers related to the fields of science under study (e.g., astrophysicist, geophysicist, astronaut) and the education and training necessary for these careers</td></tr>
</table>

<table>
<tr><td colspan="4">SNC1D</td></tr>
<tr><td colspan="4">B: SUSTAINABLE ECOSYSTEMS</td></tr>
<tr><td rowspan="2">B1</td><td colspan="2">Assess the impact of human activities on the sustainability of terrestrial and/or aquatic ecosystems, and evaluate the effectiveness of courses of action intended to remedy or mitigate negative impacts</td><td rowspan="2">Each mission has a designated Planetary Protection Officer (not an astronaut) who is responsible for 1) protecting Earth's biosphere from any negative effects arising from biotic or abiotic contaminants in the spacecraft and crew, and 2) protecting any potential biosphere or primitive abiotic environment at the destination from any contamination from Earth's biosphere.</td></tr>
<tr><td>B1.1</td><td>Assess, on the basis of research, the impact of a factor related to human activity (e.g., urban sprawl, introduction of invasive species, overhunting/overfishing) that threatens the sustainability of a terrestrial or aquatic ecosystem</td></tr>
<tr><td rowspan="3">B2</td><td colspan="2">Developing skills of investigation and communication</td><td rowspan="6">Many missions involve investigation of potential biospheres (Europa and Mars, for example). Mission goals may include looking for direct and indirect evidence of modern living organisms and biospheres or evidence of life in the past.

Investigations can include sources of metabolic energy and how it is distributed in ecosystems, how the conditions existing at the mission destination constrain the nature of organisms and their ecology, and how the conditions influence the structure and function of organisms present at the destination.</td></tr>
<tr><td>B2.1</td><td>Use appropriate terminology related to sustainable ecosystems, including, but not limited to: bioaccumulation, biosphere, diversity, ecosystem, equilibrium, sustainability, sustainable use, protection, and watershed</td></tr>
<tr><td>B2.2</td><td>Interpret qualitative and quantitative data from undisturbed and disturbed ecosystems (terrestrial and/or aquatic), communicate the results graphically, and, extrapolating from the data, explain the importance of biodiversity for all sustainable ecosystems</td></tr>
<tr><td rowspan="3">B3</td><td colspan="2">Understanding basic concepts</td></tr>
<tr><td>B3.1</td><td>Compare and contrast biotic and abiotic characteristics of sustainable and unsustainable ecosystems</td></tr>
<tr><td>B3.2</td><td>Describe the complementary processes of cellular respiration and photosynthesis with respect to the flow of energy and the cycling of matter within ecosystems and explain how human activities can disrupt the balance achieved by these processes</td></tr>
<tr><td colspan="4">C: ATOMS, ELEMENTS, AND COMPOUNDS</td></tr>
<tr><td rowspan="3">C2</td><td colspan="2">Investigate, through inquiry, the physical and chemical properties of common elements and compounds</td><td rowspan="5">Mineral, rock, and other samples are collected, catalogued, and analysed during the mission activity. Sample analysis continues after the mission activity has been completed.

The analytical tests that are carried out are, in part, dependent on the goals of the mission. Other analyses will be necessitated as a result of findings and events during the mission. Analysis of materials from within the spacecraft also may be made necessary as a result of events that take place during the mission.</td></tr>
<tr><td>C2.3</td><td>Plan and conduct an inquiry into the properties of common substances found in the laboratory or used in everyday life (e.g., starch, table salt, wax, toothpaste), and distinguish the substances by their physical and chemical properties (e.g., physical properties: hardness, conductivity, colour, melting point, solubility, density; chemical properties: combustibility, reaction with water)</td></tr>
<tr><td>C2.4</td><td>Conduct appropriate chemical tests to identify some common gases (e.g., oxygen, hydrogen, carbon dioxide) on the basis of their chemical properties, and record their observations</td></tr>
<tr><td rowspan="2">C3</td><td colspan="2">Demonstrate an understanding of the properties of common elements and compounds, and of the organization of elements in the periodic table</td></tr>
<tr><td>C3.8</td><td>Identify and use the symbols for common elements (e.g., C, Cl, S, N) and the formulae for common compounds (e.g., H_2O, CO_2, NaCl, O_2)</td></tr>
</table>

SNC1D			
D: EARTH AND SPACE SCIENCE; THE STUDY OF THE UNIVERSE			
D1	Assess the costs, hazards, and benefits of space exploration and the contributions of Canadians to space research and technology		Mission planning involves an assessment of goals of the mission and what technologies are necessary to achieve the goals. An assessment of the hazards also must be carried out. Specific hazards are listed and procedures for mitigating these are drawn up. As much as possible, each hazard will have a course of action developed for it. These procedures are practised and refined prior to the start of the mission. EEP presentation 8,11. Training or orbit software.
	D1.1	Assess, on the basis of research, and report on the contributions of Canadian governments, organizations, businesses, and/or individuals to space technology, research, and/or exploration	
	D1.2	Assess some of the costs, hazards, and benefits of space exploration (e.g., technology expences, accident risks, contributions to knowledge), taking into account the collateral benefits of technologies (e.g., radiation monitors, air quality sensors, fire-resistant materials)	
D2	Investigate the characteristics and properties of a variety of celestial objects visible from Earth in the night sky		EEP presentations 4,5,6,7,10. Training on orbit software. Parallax measurements carried out during the mission activity.
	D2.1	Use appropriate terminology related to the study of the universe, including, but not limited to: celestial objects, orbital radius, retrograde motion, and satellite	
	D2.2	Use direct observation, computer simulation, or star charts to determine the location, appearance, and motion of well-known stars and other celestial objects that are visible in the night sky (e.g., the stars Polaris, Sirius, Betelgeuse; the planet Venus)	
	D2.3	Plan and conduct a simulation that illustrates the interrelationships between various properties of celestial objects visible in the night sky (e.g., set up flashlights of various intensities at different distances from an observation point to illustrate the relationship between brightness, distance, and luminosity)	
	D2.4	Gather and record data, using an inquiry or research process, on the properties of specific celestial objects within the solar system (e.g., the composition of their atmosphere, if any; the composition of their surface; the strength of their gravitational pull)	Mission planning and execution. Simulator team gathers information on intended destination and recreates its conditions as much as possible in the constructed and virtual environment.
	D2.5	Compare and contrast properties of celestial objects visible in the night sky, drawing on information gathered through research and using an appropriate format (e.g., compare the size of planets; represent the distance of stars from Earth using scientific notation; compare star temperatures and colour)	EEP planetarium presentation. EEP presentations 5 and 6
D3	Demonstrate an understanding of the major scientific theories about the structure, formation, and evolution of the universe and its components and of the evidence that supports these theories		
	D3.1	Describe observational and theoretical evidence relating to the origin and evolution of the universe	Mission data analysis.
	D3.2	Describe observational and theoretical evidence relating to the formation of the solar system	Mission planning and data analysis
	D3.3	Describe the major components of the solar system and the universe	EEP presentations 5,6,7
	D3.4	Describe the sun's composition and energy source, and explain how its energy warms Earth and supports life on the planet	EEP presentation 5
	D3.5	Explain the causes of astronomical phenomena and how various phenomena can best be observed	EEP presentations 4,5,6,7,9,11
	D3.6	Describe various reasons that humankind has had for studying space	Mission planning and execution.

<table>
<tr><td colspan="4">SNC1D</td></tr>
<tr><td colspan="4">E: THE CHARACTERISTICS OF ELECTRICITY</td></tr>
<tr><td rowspan="3">E1</td><td colspan="2">Assess some of the costs and benefits associated with the production of electrical energy from renewable and non_renewable sources, and analyse how electrical efficiencies and savings can be achieved, through both the design of technological devices and practices in the home</td><td rowspan="3">Spacecraft power management systems operation. Fuel supplies for generating electrical energy must be managed for both the needs of the mission and for unexpected needs. Choices for different generation methods can be made, each with different efficiencies, capacities, safety concerns, and requirements for fuel and oxidizers.
Total fuel supply must be tailored to mission goals as well as safety considerations for such things as engine failure on liftoff.</td></tr>
<tr><td>E1.1</td><td>Analyse the design of a technological device that improves its electrical efficiency or protects other devices by using or controlling static electricity (e.g., paint sprayers, photocopiers, lightning rods, grounding wires)</td></tr>
<tr><td>E1.3</td><td>Produce a plan of action to reduce electrical energy consumption at home (e.g., using EnerGuide information when purchasing appliances), and outline the roles and responsibilities of various groups (e.g., government, business, family members) in this endeavour</td></tr>
<tr><td rowspan="11">E2</td><td colspan="3">Investigate, through inquiry, aspects of electricity, including properties of static and current electricity, and quantitative relationships between potential difference, current, and resistance in electrical circuits</td></tr>
<tr><td>E2.1</td><td>Use appropriate terminology related to electricity, including, but not limited to: ammeter, amperes, battery, current, fuse, kilowatt hours, load, ohms, potential difference, resistance, switch, voltmeter, and volts</td><td>Spacecraft circuit design.
Spacecraft power systems management.</td></tr>
<tr><td>E2.2</td><td>Conduct investigations into the transfer of static electric charges by friction, contact, and induction, and produce labelled diagrams to explain the results</td><td rowspan="3">EEP static electricity presentation.</td></tr>
<tr><td>E2.3</td><td>Predict the ability of different materials to hold or transfer electric charges (i.e., to act as insulators or conductors), and test their predictions through inquiry</td></tr>
<tr><td>E2.4</td><td>Plan and carry out inquiries to determine and compare the conductivity of various materials (e.g., metals, plastics, glass, water)</td></tr>
<tr><td>E2.5</td><td>Design, draw circuit diagrams of, and construct series and parallel circuits (e.g., a circuit where all light bulbs go out when one light bulb is removed; a circuit that allows one of several light bulbs to be switched on and off independently of the others), and measure electric current I, potential difference V, and resistance R at various points in the circuits, using appropriate instruments and SI units</td><td>Design and construction of low-voltage circuits for controlling systems within the spacecraft such as door sensors, control panels, and auxilliary communication systems.

Sensor systems and control systems run on 5V DC and incorporate switches, LED indicators, logic circuits, and must communicate with computer software using parallel, serial, and USB ports using student made controllers and arduino microcontrollers.</td></tr>
<tr><td>E2.6</td><td>Analyse and interpret the effects of adding an identical load in series and in parallel in a simple circuit</td><td>Spacecraft circuit design.
Spacecraft power systems management.</td></tr>
<tr><td>E2.7</td><td>Investigate the quantitative relationships between current, potential difference, and resistance in a simple series circuit</td><td>Spacecraft circuit design.
Spacecraft power systems management.</td></tr>
<tr><td>E2.8</td><td>Solve simple problems involving potential difference V, electric current I, and resistance R, using the quantitative relationship V = IR</td><td>Spacecraft circuit design.
Spacecraft power systems management.</td></tr>
<tr><td>E2.9</td><td>Determine the energy consumption of various appliances, and calculate their operating costs (e.g., using the kilowatt hour rate from a utility bill)</td><td rowspan="2">Spacecraft power systems and fuel management</td></tr>
<tr><td>E2.10</td><td>Calculate the efficiency of an energy converter, using the following equation:
percent efficiency = (Eout/Ein)x100%</td></tr>
</table>

<table>
<tr><td colspan="4">SNC1D</td></tr>
<tr><td rowspan="8">E3</td><td colspan="3">Demonstrate an understanding of the principles of static and current electricity.</td></tr>
<tr><td>E3.1</td><td>Identify electrical quantities (i.e., current, potential difference, resistance, and electrical energy), and list their symbols and their corresponding SI units (e.g., electric current: I, ampere)</td><td>Spacecraft circuit design (see E2.5)</td></tr>
<tr><td>E3.2</td><td>Explain the characteristics of conductors and insulators and how materials allow static charge to build up or be discharged</td><td>EEP static electricity demonstration.</td></tr>
<tr><td>E3.4</td><td>Identify the components of a simple DC circuit (e.g., electrical source, load, connecting wires, switch, fuse), and explain their functions</td><td rowspan="5">Spacecraft circuit design (see E2.5).

Troubleshooting of low voltage electrical systems during the mission activity.

Management of the onboard electrical power distribution system (EPDS).
EPDS management requires understanding a system involving multiple parallel power busses that can be cross-connected in different ways. Each bus has one or more different independent (parallel) electrical generating systems and a number of different parallel loads. Students must learn to operate the system such that loads are supplied with sufficient current, that generators are not over-taxed (resulting in overheating and voltage drops), that fuel use rates stay within acceptable limits, and that all spacecraft systems are operating as necessary to meet mission goals and ensure safe operation of the spacecraft.

Students also must monitor the system for signs of malfunctions, short circuits, fuel leaks, and other issues.</td></tr>
<tr><td>E3.5</td><td>Explain the characteristics of electric current, potential difference, and resistance in simple series and parallel circuits, noting how the quantities differ in the two circuits</td></tr>
<tr><td>E3.6</td><td>Describe, qualitatively, the interrelationships between resistance, potential difference, and electric current (e.g., the effect on current when potential difference is changed and resistance is constant)</td></tr>
<tr><td>E3.7</td><td>Explain what different meters (e.g., ammeters, voltmeters, multimeters) measure and how they are connected within an electrical circuit to measure electrical quantities</td></tr>
<tr><td>E3.8</td><td>Explain how various factors (e.g., wire length, wire material, cross-sectional area of wire) influence the resistance of an electrical circuit</td></tr>
</table>

Grade 9 Science SNC1P			
A, B, C: similar to SNC1D			
D: SPACE EXPLORATION			
D1	Analyse the major challenges and benefits of space exploration, and assess the contributions of Canadians to space exploration		
	D1.1	Research the challenges associated with space exploration, and explain the purpose of materials and technologies that were developed to address these challenges and how these materials and technologies are now used in other fields of endeavour (e.g., robotic arm technology developed for the space program is used in industry to handle hazardous chemicals; synthetic materials developed to protect astronauts are used in fire-fighting equipment) Sample questions: Why is radiation a particular hazard for astronauts; how is it monitored and mitigated?	EEP presentations 1,2,3,8,10,11. Training on orbit software. Training on EECOM software.
	D1.2	Assess the contributions of Canadians to space exploration (e.g., as astronauts; in research and development)	Research for mission goals.
D2	Investigate the properties of different types of celestial objects in the solar system and the universe		
	D2.1	Use appropriate terminology related to space exploration, including, but not limited to: astronomical units, gravitational pull, and universe	Planetarium presentation. EEP presentations 2,4,6,8,10 Mission planning and execution. Training on orbit software.
	D2.2	Investigate patterns in the night sky (e.g., constellations) and the motion of celestial objects (e.g., the sun, our moon, planets, stars, galaxies), using direct observation, computer simulations, and/or star charts, and record the information using a graphic organizer or other format	Planetarium presentation.
	D2.3	Use a research process to compile and analyse information on the characteristics of various objects in the universe (e.g., planets, stars, constellations, galaxies)	Mission planning.
	D2.4	Investigate a technological challenge related to the exploration of celestial objects that arises from the objects' specific properties, and identify the solution that has been devised (e.g., multiple booster rockets power spacecraft travelling to distant planets; heat shields protect the space shuttle from extreme temperatures when re-entering Earth's atmosphere)	Mission planning. Training on orbit and EECOM software. EEP presentations 2,3, 8,10,11
D3	Demonstrate an understanding of major astronomical phenomena and of the principal components of the solar system and the universe		
	D3.1	Describe the major components of the universe (e.g., planets, moons, stars, galaxies), the motion of the different types of celestial objects, and the distances between certain objects, using appropriate scientific terminology and units (e.g., astronomical units, light years)	EEP presentations 4,5,6,7,9 Mission planning
	D3.2	Compare the characteristics and properties of celestial objects that constitute the solar system, including their motion and their distance from other celestial objects in the solar system (e.g., composition, size, rotation, presence and composition of atmosphere, gravitational pull, magnetic field)	EEP presentations 4,5,6,7,9 Mission planning
	D3.3	Identify the factors that make Earth well suited for the existence of life (e.g., a magnetosphere that protects the planet from solar wind; Earth's distance from the sun; the ability of Earth's atmosphere to trap heat, preventing extreme fluctuations in temperature)	Training on EECOM software. Mission planning. EEP presentations 5,6.
	D3.4	Describe the characteristics of the sun and the effects of its energy on Earth and Earth's atmosphere	Training on EECOM software. EEP presentation 5
	D3.5	Describe the causes of major astronomical phenomena (e.g., the aurora borealis, solar/lunar eclipses) and how various phenomena can best be observed from Earth	EEP presentation 5,9

Grade 10 Science SNC2D			
A: SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION			
A1	Demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating)		SNC1D A1.1 to A1.13
A2	Identify and describe a variety of careers related to the fields of science under study, and identify scientists, including Canadians, who have made contributions to those fields		
	A2.1	Identify and describe a variety of careers related to the fields of science under study (e.g., meteorologist, medical illustrator, geochemist, optical physicist) and the education and training necessary for these careers	See SNC1D

B: TISSUES, ORGANS, AND SYSTEMS OF LIVING THINGS			
B2	Investigate cell division, cell specialization, organs, and systems in animals and plants, using research and inquiry skills, including various laboratory techniques		
	B2.3	Examine different plant and animal cells (e.g., cheek cells, onion cells) under a microscope or similar instrument, and draw labelled biological diagrams to show how the cells' organelles differ	Microscopic examination and description of planetary surface samples such as found on MER2012A on the 2013 mission.

C: CHEMICAL REACTIONS			
C2	Investigate, through inquiry, the characteristics of chemical reactions		Analysis of planetary surface samples. Can include titration for acid/base content, pH measurement, and concentration of significant inorganic ions such as phosphate, nitrate, ammonium, sulphate.
	C2.1	Use appropriate terminology related to chemical reactions, including, but not limited to: compounds, product, and reactant	
	C2.6	Plan and conduct an inquiry to classify some common substances as acidic, basic, or neutral (e.g., use acid-base indicators or pH test strips to classify common household substances)	
C3	Demonstrate an understanding of the general principles of chemical reactions, and various ways to represent them		Chemical analysis of planetary samples and evaluation of the potential for planetary environments for supporting life.
	C3.6	Describe the process of acid-base neutralization (i.e., an acid reacts with a base to form a salt and often water)	
	C3.7	Describe how the pH scale is used to classify solutions as acidic, basic, or neutral (e.g., a solution with a pH of 1 is highly acidic; a solution with a pH of 7 is neutral)	

D: CLIMATE CHANGE			
D2	Investigate various natural and human factors that influence Earth's climate and climate change		
	D2.1	Use appropriate terminology related to climate change, including, but not limited to: albedo, anthropogenic, atmosphere, cycles, heat sinks, and hydrosphere	Mission goal planning. Measurements taken in orbit and on the surface of the mission destination.
	D2.3	Analyse different sources of scientific data (e.g., lake cores, tree rings, fossils and preserved organisms, ice cores) for evidence of natural climate change and climate change influenced by human activity	Depending on mission goals, analysis of large-scale processes on the destination planet could include consideration of energy and water cycles. Investigation of planetary-scale processes would aid in our understanding of such processes on earth and how they might respond to changes in various parameters.
	D2.5	Investigate, through laboratory inquiry or simulations, the effects of heat transfer within the hydrosphere and atmosphere	
	D2.6	Investigate, through laboratory inquiry or simulations, how water in its various states influences climate patterns (e.g., water bodies moderate climate, water vapour is a greenhouse gas, ice increases the albedo of Earth's surface)	
	D2.7	Investigate, through research or simulations, the influence of ocean currents on local and global heat transfer and precipitation patterns	

SNC2D

<table>
<tr><td rowspan="4">D3</td><td colspan="3">Demonstrate an understanding of natural and human factors, including the greenhouse effect, that influence Earth's climate and contribute to climate change</td></tr>
<tr><td>D3.1</td><td>Describe the principal components of Earth's climate system (e.g., the sun, oceans, and atmosphere; the topography and configuration of land masses) and how the system works</td><td rowspan="3">Depending on mission goals, analysis of large-scale processes on the destination planet could include consideration of energy and water cycles as well as investigations into how these are affected by components in the atmosphere. Investigation of planetary-scale processes would aid in our understanding of such processes on earth and how they might respond to changes in various parameters.</td></tr>
<tr><td>D3.2</td><td>Describe and explain heat transfer in the hydrosphere and atmosphere and its effects on air and water currents</td></tr>
<tr><td>D3.3</td><td>Describe the natural greenhouse effect, explain its importance for life, and distinguish it from the anthropogenic greenhouse effect</td></tr>
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<tr><td colspan="4">E: LIGHT AND GEOMETRIC OPTICS</td></tr>
<tr><td rowspan="3">E1</td><td colspan="2">Evaluate the effectiveness of technological devices and procedures designed to make use of light, and assess their social benefits</td><td rowspan="3">EEP presentation 9
Infrared sensors within the spacecraft functioning as switches for engineering systems.</td></tr>
<tr><td>E1.1</td><td>Analyse a technological device or procedure related to human perception of light (e.g., eyeglasses, contact lenses, infrared or low light vision sensors, laser surgery), and evaluate its effectiveness</td></tr>
<tr><td>E1.2</td><td>Analyse a technological device that uses the properties of light (e.g., microscope, retro-reflector, solar oven, camera), and explain how it has enhanced society</td></tr>
<tr><td rowspan="3">E3</td><td colspan="3">Demonstrate an understanding of various characteristics and properties of light, particularly with respect to reflection in mirrors and reflection and refraction in lenses</td></tr>
<tr><td>E3.1</td><td>Describe and explain various types of light emissions (e.g., chemiluminescence, bioluminescence, incandescence, fluorescence, phosphorescence, triboluminescence; from an electric discharge or light-emitting diode [LED])</td><td>Remote sensing systems such as induced bioluminescent emissions from microscopic life and reflectance spectroscopy.</td></tr>
<tr><td>E3.6</td><td>Identify ways in which the properties of mirrors and lenses (both converging and diverging) determine their use in optical instruments (e.g., cameras, telescopes, binoculars, microscopes)</td><td>EEP presentation 9</td></tr>
</table>

Chemistry SCH3U			
A: Scientific Investigation Skills and Career Exploration			
A1	Demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating)		See SNC1D A1.1 to A1.13

C: Chemical Reactions			
C2	Investigate different types of chemical reactions		
	C2.1	Use appropriate terminology related to chemical reactions, including, but not limited to: neutralization, precipitate, acidic, and basic	Chemical analysis of planetary samples for identification of minerals and surface/subsurface water contaminants.
	C2.2	Write balanced chemical equations to represent synthesis, decomposition, single displacement, double displacement, and combustion reactions, using the IUPAC nomenclature system	
	C2.3	Investigate synthesis, decomposition, single displacement, and double displacement reactions, by testing the products of each reaction (e.g., test for products such as gases, the presence of an acid, or the presence of a base)	
C3	Demonstrate an understanding of the different types of chemical reactions		
	C3.1	Identify various types of chemical reactions, including synthesis, decomposition, single displacement, double displacement, and combustion	Chemical analysis of planetary samples for identification of minerals and surface/subsurface water contaminants.

D: Quantities in Chemical Reactions			
D1	Analyse processes in the home, the workplace, and the environmental sector that use chemical quantities and calculations, and assess the importance of quantitative accuracy in industrial chemical processes		Planning for chemical analysis of planetary samples.
	D1.1	Analyse processes in the home, the workplace, and the environmental sector that involve the use of chemical quantities and calculations (e.g., mixing household cleaning solutions, calculating chemotherapy doses, monitoring pollen counts)	
D2	Investigate quantitative relationships in chemical reactions, and solve related problems		Chemical analysis of planetary samples for identification of minerals and surface/subsurface water contaminants.
	D2.1	Use appropriate terminology related to quantities in chemical reactions, including, but not limited to: stoichiometry, percentage yield, limiting reagent, mole, and atomic mass	
	D2.4	Determine the empirical formulae and molecular formulae of various chemical compounds, given molar masses and percentage composition or mass data	

<table>
<tr><td colspan="4">SCH3U</td></tr>
<tr><td colspan="4">E: Solutions and Solubility</td></tr>
<tr><td rowspan="6">E2</td><td colspan="2">Investigate qualitative and quantitative properties of solutions, and solve related problems</td><td rowspan="6">Chemical analysis of planetary samples for identification of minerals and surface/subsurface water contaminants and their concentrations.</td></tr>
<tr><td>E2.1</td><td>Use appropriate terminology related to aqueous solutions and solubility, including, but not limited to: concentration, solubility, precipitate, ionization, dissociation, pH, dilute, solute, and solvent</td></tr>
<tr><td>E2.3</td><td>Prepare solutions of a given concentration by dissolving a solid solute in a solvent or by diluting a concentrated solution</td></tr>
<tr><td>E2.4</td><td>Conduct an investigation to analyse qualitative and quantitative properties of solutions (e.g., perform a qualitative analysis of ions in a solution)</td></tr>
<tr><td>E2.7</td><td>Determine the concentration of an acid or a base in a solution (e.g., the concentration of acetic acid in vinegar), using the acid-base titration technique</td></tr>
<tr><td>E2.8</td><td>Conduct an investigation to determine the concentrations of pollutants in their local treated drinking water, and compare the results to commonly used guidelines and standards (e.g., provincial and federal standards)</td></tr>
<tr><td rowspan="2">E3</td><td colspan="2">Demonstrate an understanding of qualitative and quantitative properties of solutions</td><td rowspan="2">Chemical analysis of planetary samples for identification of minerals and surface/subsurface water contaminants.</td></tr>
<tr><td>E3.4</td><td>Identify, using a solubility table, the formation of precipitates in aqueous solutions (e.g., the use of iron or aluminum compounds to precipitate and remove phosphorus from wastewater)</td></tr>
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<table>
<tr><td colspan="4">F: Gases and Atmospheric Chemistry</td></tr>
<tr><td rowspan="2">F1</td><td colspan="2">Analyse the cumulative effects of human activities and technologies on air quality, and describe some Canadian initiatives to reduce air pollution, including ways to reduce their own carbon footprint</td><td rowspan="2">Management of pollutants within the environment of the spacecraft, especially in response to events such as fire, coolant leaks, and contamination from outside environments.</td></tr>
<tr><td>F1.1</td><td>Analyse the effects on air quality of some technologies and human activities (e.g., smelting; driving gas-powered vehicles), including their own activities, and propose actions to reduce their personal carbon footprint</td></tr>
<tr><td rowspan="4">F2</td><td colspan="2">Investigate gas laws that explain the behaviour of gases, and solve related problems</td><td rowspan="4">Development for algorithms for EECOM software.

Management of EECOM software and understanding of best practices for maintaining a safe environment within the spacecraft, especially in response to loss of atmospheric integrity.</td></tr>
<tr><td>F2.1</td><td>Use appropriate terminology related to gases and atmospheric chemistry, including, but not limited to: standard temperature, standard pressure, molar volume, and ideal gas</td></tr>
<tr><td>F2.2</td><td>Determine, through inquiry, the quantitative and graphical relationships between the pressure, volume, and temperature of a gas</td></tr>
<tr><td>F2.3</td><td>Solve quantitative problems by performing calculations based on Boyle's law, Charles's law, Gay-Lussac's law, the combined gas law, Dalton's law of partial pressures, and the ideal gas law</td></tr>
</table>

SCH3U			
F3	Demonstrate an understanding of the laws that explain the behaviour of gases		
	F3.1	Identify the major and minor chemical components of Earth's atmosphere	Analysis or atmospheric components and the extent/amount of atmosphere present as a function of the size, composition, and location of the destination object.
	F3.3	Use the kinetic molecular theory to explain the properties and behaviour of gases in terms of types and degrees of molecular motion	Development of algorithms for EECOM software.
	F3.4	Describe, for an ideal gas, the quantitative relationships that exist between the variables of pressure, volume, temperature, and amount of substance	
	F3.5	Explain Dalton's law of partial pressures, Boyle's law, Charles's law, Gay-Lussac's law, the combined gas law, and the ideal gas law	
	F3.6	Explain Avogadro's hypothesis and how his contribution to the gas laws has increased our understanding of the chemical reactions of gases	

Chemistry SCH4C			
A: Scientific Investigation Skills and Career Exploration			
A1	Demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating)		See SNC1D
B: Matter and Qualitative Analysis			
B1	Evaluate the effects of chemical substances on the environment, and analyse practical applications of qualitative analysis of matter		Chemical/mineralogical analysis of samples from planetary surface. Planning of experiments for this purpose. Interpretation of analytical results in respect of mission goals and in respect of any unexpected findings.
	B1.2	Analyse, on the basis of research, applications of qualitative analysis of matter in various fields of endeavour (e.g., in law enforcement to detect drugs or identify counterfeit money)	
B2	Investigate matter, using various methods of qualitative analysis		
	B2.1	Use appropriate terminology related to qualitative analysis of matter, including, but not limited to: double displacement, precipitate, and energy level	
	B2.2	Use a table of solubility rules to write chemical equations for double displacement reactions and to write balanced net ionic equations for chemical reactions	
	B2.3	Investigate precipitation reactions and flame tests, using qualitative analysis instruments, equipment, and techniques (e.g., gas discharge tubes, high-voltage electrical sources, spectroscope, centrifuge)	
	B2.4	Conduct qualitative analyses of an unknown sample (e.g., a household or workplace chemical), using a flow chart and experimental procedures, including flame tests and precipitation reactions, to determine the presence of metal ions	
	B2.5	Identify an unknown gas sample (e.g., hydrogen, helium, neon) by observing its emission spectrum and comparing it to the spectra of known gases	
	B2.6	Use a table of solubility rules to predict if a precipitate will form in a given chemical reaction, and identify the precipitate formed	

<table>
<tr><td colspan="4">SCH4UC</td></tr>
<tr><td rowspan="4">B3</td><td colspan="3">Demonstrate an understanding of the basic principles of qualitative analysis of matter</td></tr>
<tr><td>B3.1</td><td>Explain the relationship between the atomic number and the mass number of an element, and the difference between isotopes and radioisotopes of an element</td><td>Use of isotopic ratios to investigate provenance of samples.</td></tr>
<tr><td>B3.2</td><td>Describe various types of chemical reactions, including synthesis, decomposition, single displacement, and double displacement reactions</td><td rowspan="2">Chemical/mineralogical analysis of samples from planetary surface.
Planning of experiments for this purpose.
Interpretation of analytical results in respect of mission goals and in respect of any unexpected findings.</td></tr>
<tr><td>B3.3</td><td>Explain basic procedures used in qualitative analysis of elements and compounds, including flame tests, precipitation reactions, and the observation of emission spectra</td></tr>
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<table>
<tr><td colspan="4">C: Organic Chemistry</td></tr>
<tr><td rowspan="6">C2</td><td colspan="2">Investigate the physical and chemical properties of organic compounds, and analyse some common organic chemical reactions</td><td rowspan="9">Collect samples of organic matter from comets and other bodies, such as was carried out on moons of the Saturn system in the 2015 mission.

Physical properties are investigated as well as spectroscopic analysis and mass spectrometry.

Simple organic molecules are common in the outer solar system and in interstellar space in general. The analysis of these materials is part of investigations into the origins of life on earth and elsewhere.</td></tr>
<tr><td>C2.1</td><td>Use appropriate terminology related to organic chemistry, including, but not limited to: electronegativity, covalent bond, and functional group</td></tr>
<tr><td>C2.2</td><td>Draw Lewis structures to represent the covalent bonds in some simple organic mol-ecules (e.g., CH_4)</td></tr>
<tr><td>C2.3</td><td>Build molecular models of, and create structural formulae for, some simple organic molecules (e.g., methane, butane, ethyne)</td></tr>
<tr><td>C2.4</td><td>Conduct an inquiry to determine the physical and chemical properties of some common organic compounds (e.g., solubility [in polar and non-polar solvents], conductivity, odour, combustibility)</td></tr>
<tr><td>C2.5</td><td>Conduct an inquiry to demonstrate separation of a mixture of liquids by distillation</td></tr>
<tr><td rowspan="3">C3</td><td colspan="2">Demonstrate an understanding of the structure and the physical and chemical properties of organic compounds</td></tr>
<tr><td>C3.5</td><td>Explain how the physical properties of a substance affect the processes used to separate organic chemical substances (e.g., distillation of crude oil, distillation of alcohols)</td></tr>
<tr><td>C3.6</td><td>Identify the first ten hydrocarbons of the alkanes, the alkenes, and the alkynes by their names and structural formulae, using International Union of Pure and Applied Chemistry (IUPAC) nomenclature for alkanes, alkenes, and alkynes</td></tr>
<tr><td colspan="4">E: Chemical Calculations</td></tr>
<tr><td rowspan="4">E2</td><td colspan="2">Investigate chemical compounds and chemical reactions using appropriate techniques of quantitative analysis, and solve related problems</td><td rowspan="4">Carry out quantitative and qualitative analysis of mineral, atmosphere, and water samples from the planetary surface.

These will include procedures such as titration, spectrospcopy, and sequential precipitation analysis.</td></tr>
<tr><td>E2.1</td><td>Use appropriate terminology related to stoichiometry, including, but not limited to: molar mass, molar concentration, percentage yield, and Avogadro's number</td></tr>
<tr><td>E2.7</td><td>Use qualitative observations of a chemical reaction to identify the chemical changes, presence of limiting reagents, and the products</td></tr>
<tr><td>E2.8</td><td>Prepare aqueous solutions of given concentrations (e.g., concentrations expressed in grams per litre or moles per litre) by dissolving a solid solute in a solvent or by diluting a concentrated solution (e.g., a stock solution)</td></tr>
</table>

SCH4C			
E3	Demonstrate an understanding of the mole concept and its quantitative relationships in chemical reactions		
	E3.2	Describe some possible sources of experimental error in an investigation of a chemical reaction, and explain how the errors would affect the percentage yield of products of the reaction	These concepts are important to understand the limits of what conclusions can be drawn from the chemical analysis of planetary samples, especially the limits of precision in any attempts to discriminate between different possible conclusions.
	E3.4	Explain the concept of molar concentration of a solution, using appropriate units of measure	
	E3.5	Explain the concept of a limiting reagent in a chemical reaction, using examples of chemical processes from everyday life	

F: Chemistry in the Environment			
F1	Evaluate the importance of government regulations, scientific analyses, and individual actions in improving air and water quality, and propose a personal plan of action to support these efforts		Management of pollutants within the environment of the spacecraft, especially in response to events such as fire, coolant leaks, and contamination from outside environments. Management of safe potable water supplies within the spacecraft, including testing and identification of threats to health.
	F1.2	Evaluate the importance of quantitative chemical analysis in assessing air and water quality (e.g., the use of Environment Canada's Air Quality Index to determine when smog advisories need to be issued; systems to monitor the quality of drinking water), and explain how these analyses contribute to environmental awareness and responsibility	
F2	Investigate chemical reactions, using appropriate techniques of quantitative analysis		Carry out quantitative and qualitative analysis of mineral, atmosphere, and water samples from the planetary surface. Investigate procedures and technology for carrying out chemical analyses that can be carried out or simulated as part of the mission and post-mission procedures.
	F2.1	Use appropriate terminology related to chemical analysis and chemistry in the environment, including, but not limited to: ozone, hard water, titration, pH, ppm, and ppb	
	F2.2	Write balanced chemical equations to represent the chemical reactions involved in the neutralization of acids and bases	
	F2.3	Conduct an acid-base titration to determine the concentration of an acid or a base (e.g., the concentration of acetic acid in vinegar)	
	F2.4	Conduct an inquiry, using available technology or chemical tests, to detect the presence of inorganic substances in various samples of water	
F3	Demonstrate an understanding of chemical reactions that occur in the environment as a result of both natural processes and human activities		
	F3.1	Identify major and minor chemical components of Earth's atmosphere	Carry out chemical analyses of atmosphere samples and carry out remote sensing analysis of the atmosphere at the destination. Identify any structure to the atmosphere at the destination.
	F3.2	Identify gases and particulates that are commonly found in the atmosphere, and explain how they affect air quality (e.g., greenhouse gases, tropospheric and stratospheric ozone, carbon monoxide, chlorofluorocarbons, soot)	
	F3.5	Identify the gas emissions that are the major contributors to acid precipitation, and explain the steps in the formation of acid rain	Carry out quantitative and qualitative analysis of mineral, atmosphere, and water samples from the planetary surface.
	F3.6	Explain the difference between the concepts of strength and concentration when referring to solutions of acids and bases	
	F3.7	Identify inorganic substances that can be found dissolved in water as a result of natural processes and human activities (e.g., hard water contains metal ions)	

<table>
<tr><td colspan="4">Chemistry SCH4U</td></tr>
<tr><td colspan="4">B: Organic Chemistry</td></tr>
<tr><td rowspan="2">B2</td><td colspan="2">Investigate organic compounds and organic chemical reactions, and use various methods to represent the compounds</td><td rowspan="2">Procedures for analysis of planetary samples to test for the presence of organic compounds and evidence of metabolic activity.</td></tr>
<tr><td>B2.4</td><td>Analyse, on the basis of inquiry, various organic chemical reactions (e.g., production of esters, polymerization, oxidation of alcohols, multiple bonds in an organic compound, combustion reactions, addition reactions)</td></tr>
</table>

<table>
<tr><td colspan="4">Biology SBI4U</td></tr>
<tr><td colspan="4">B: Biochemistry</td></tr>
<tr><td rowspan="3">B2</td><td colspan="3">Investigate the chemical structures, functions, and chemical properties of biological molecules involved in some common cellular processes and biochemical reactions</td></tr>
<tr><td>B2.4</td><td>Conduct biological tests to identify biochemical compounds found in various food samples (e.g., use Benedict’s solution to test for carbohydrates in food samples), and compare the biochemical compounds found in each food to those found in the others</td><td>Procedures to test for specific biochemical compounds in planetary samples.</td></tr>
<tr><td>B2.5</td><td>Plan and conduct an investigation related to a cellular process (e.g., factors that affect enzyme activity; factors that affect transport of substances across cell membranes), using appropriate laboratory equipment and techniques, and report the results in an appropriate format</td><td>Procedures to test for enzyme activity and other direct and indirect evidence for biological activity in planetary samples.</td></tr>
<tr><td colspan="4">C: Metabolic Processes</td></tr>
<tr><td rowspan="3">C2</td><td colspan="2">Investigate the products of metabolic processes such as cellular respiration and photosynthesis</td><td rowspan="3">Direct and indirect tests for biological activity including the production biochemical compounds by activity similar to photosynthesis or chemosynthesis and the conversion of biochemical compounds into metabolic end products.</td></tr>
<tr><td>C2.2</td><td>Conduct a laboratory investigation into the process of cellular respiration to identify the products of the process, interpret the qualitative observations, and display them in an appropriate format</td></tr>
<tr><td>C2.3</td><td>Conduct a laboratory investigation of the process of photosynthesis to identify the products of the process, interpret the qualitative observations, and display them in an appropriate format</td></tr>
</table>

Earth and Space Science SES4U			
A: Scientific Investigation Skills and Career Exploration			
A1	Demonstrate scientific investigation skills (inquiry and research) in the four areas of skills (initiating and planning, performing & recording, analysing & interpreting, and communicating)		See SCH3U
B: Astronomy			
B1	Analyse the development of technologies that have contributed to our understanding of the universe, and evaluate the impact of milestones in astronomical theory or knowledge on the scientific community		Establish what are scientifically significant goals for missions and what technologies are necessary to be simulated or implemented to achieve these goals.
	B1.1	Analyse a milestone in astronomical knowledge or theory (e.g., galactic red shift), and explain how it revolutionized thinking in the scientific community	
	B1.2	Analyse why and how an astronomical technology has developed improved over time (e.g., the evolution from optical to radio telescopes and to the Hubble telescope)	
B2	Investigate and analyse the properties of the universe, particularly the evolution and properties of stars, in both qualitative and quantitative terms		
	B2.1	Use appropriate terminology related to astronomy, including: Doppler effect, electromagnetic radiation, protostar, celestial equator, ecliptic, altitude and azimuth, and right ascension and declination	Planetarium presentations. Navigation training for orbit procedures.
	B2.2	Locate observable features of the night sky using star charts, computer models, or direct observation, and record the location of these features using astronomical terms (e.g., celestial equator, ecliptic) and systems (e.g., altitude and azimuth, right ascension and declination)	
	B2.3	Analyse spectroscopic data mathematically or graphically to determine various properties of stars (e.g., surface temperature from peak wavelength using Wein's law; chemical composition from spectral absorption lines; motion using the Doppler effect)	Astrometric observations carried out as part of the mission activity.
	B2.4	Use the Hertzsprung-Russell diagram to determine the interrelationships between the properties of stars (e.g., mass vs luminosity, colour vs luminosity) and to investigate their evolutionary pathways	Planetarium presentations.
	B2.5	Investigate, in quantitative terms, properties of stars, including their distance from Earth (parallax), surface temperature, absolute magnitude, and luminosity	Planetarium presentations. Parallax and other astrometric observations carried out during the mission activity.
B3	Demonstrate an understanding of the origin and evolution of the universe, the principal characteristics of its components, and techniques used to study those components		
	B3.2	Explain the scale of distances between celestial bodies and the methods used to determine these distances	Planetarium presentations. EEP presentation 6 Training and piloting on orbit software.
	B3.3	Describe the characteristics of electromagnetic radiation (λ, f, E) and the uses for each part of the spectrum	EECOM radiation management.
	B3.4	Explain how stars are classified on the basis of surface temperature, luminosity, and chemical composition	Planetarium presentations.
	B3.5	Explain using specific stars determine the properties of stars (mass, diameter, temperature, luminosity)	Planetarium presentations.
	B3.6	Describe the life cycle of a star from its formation to the main sequence phase and beyond, with specific reference to energy sources and forces involved	Planetarium presentations.
	B3.7	Explain the relationship between final state of a star and the its initial mass	Planetarium presentations.

SES4U			
C: Planetary Science			
C1	Analyse political, economic, and environmental issues related to the exploration and study of the solar system, and how technology used in space exploration can be used in other areas of endeavour		Mission Planning and justification. EEP presentations 8,11. Simulator training and implementation of simulation plans and procedures. Investigation of research or spacecraft technologies that might be implemented or simulated as part of a mission.
	C1.1	Analyse political considerations related to, and economic and environmental consequences (actual and/or potential) of, exploration of the solar system (e.g., political pressures underlying the original Space Race; monitoring environmental conditions from space)	
	C1.2	Analyse, on the basis of research, a specific technology that is used in space exploration and that has applications in other areas of research or in the environmental sector (Canadian satellites and robotics, spacecraft technologies, ground base and orbital telescopes,), and communicate their findings	
C2	Investigate features of and interactions between bodies in the solar system, and the impact of these features and interactions on the existence of life		
	C2.1	Use appropriate terminology related to planetary science, including, but not limited to: solar system, geocentric, heliocentric, geodesy, geosynchronous, eccentricity, apogee, aphelion, perigee, and perihelion	EEP presentation 2,11. Orbit software training and piloting.
	C2.2	Identify geological features and processes that are common to Earth and other bodies in the solar system (e.g., craters, faults, volcanic eruptions), and create a model or illustration to show these features, using data and images from satellites and space probes	Mission planning and implementation.
	C2.3	Use an inquiry or research process to investigate the effects of various forms of radiation and high-energy particles on bodies, organisms, and devices within the solar system (effects of cosmic rays on atmospheric phenomena, of ultraviolet light on human and animal eyes and skin, of solar wind on radio communications)	EECOM systems management. Simulator training and management. Mission planning.
	C2.4	Investigate the ways in which interactions between solid bodies have helped to shape the solar system, including Earth (e.g., the accretion of minor bodies, the formation of moons, the formation of planetary rings)	EEP presentation 5. Mission planning.
	C2.5	Investigate the properties of Earth that protect life from hazards such as radiation and collision with other bodies (e.g., Earth's orbital position helps protect it from asteroids, some are deflected by the Jovian planets; magnetic field protects planet from solar wind; atmospheric ozone minimizes incoming UV radiation)	EEP presentation 5.
	C2.6	Investigate techniques used to study and understand objects in the solar system (e.g., the measurement of gravitational pull on space probes to determine the mass of an object, the use of spectroscopy to study atmospheric compositions, the use of the GPS to track plate movement and tectonic activity from space)	EEP presentation 11 Mission planning.

SES4U			
C3	Demonstrate an understanding of the internal (geological) processes and external (cosmic) influences operating on bodies in the solar system		
	C3.1	Explain the composition of the solar system (e.g., the sun, terrestrial inner planets, asteroid belt, gas giant outer planets, Kuiper belt, scattered disc, heliopause, Oort cloud), and describe the characteristics of each	EEP presentation 5 Mission planning. Simulator training and planning.
	C3.2	Identify and explain the classes of objects orbiting the sun (planets, dwarf planets, small solar system bodies)	
	C3.3	Explain the formation of the solar system with reference to the fundamental forces and processes involved (e.g., gravitational contraction of the original solar nebula)	
	C3.4	Identify the factors that determined the properties of bodies in the solar system (e.g., differences in distance from the sun result in temperature variations that determine whether substances on a planet, moon, or other body are solid or gaseous)	
	C3.5	Identify and explain the properties of celestial bodies within or beyond the solar system, other than Earth, that might support the existence of life (e.g., possible liquid water on Europa; proximity of a body to its host star)	
	C3.6	Compare Earth with other objects in the solar system with respect to properties: mass, size, composition, rotation, magnetic field, and gravitational field	
	C3.7	Identify Kepler's laws, and use them to describe planetary motions (e.g., the shape of their orbits; differences in their orbital velocity)	EEP presentations 1,2,3,4,5 Orbit software training.
	C3.8	Identify Newton's laws, and use them to explain planetary motion	Orbit software training.
	C3.9	Describe the major external processes and phenomena that affect Earth (e.g., radiation and particles from the "quiet" and "active" sun; cosmic rays; gravity of the sun and moon; asteroidal and cometary debris, including their force, energy, and matter)	EEP presentation 5 EECOM software training and management. Piloting. Simulator training and planning.

D: Recording Earth's Geological History			
D2	Investigate geological evidence of major changes that have occurred during Earth's history, and of the various processes that have contributed to these changes		Mission planning. Training for and carrying out geological and geographical measurements during mission activities. Planning, designing, and construction of planetary surface and specific features and collectables to be integrated into the surface as well as features to integrate into the simulated environment.
	D2.1	Use appropriate terminology related to Earth and its geological history, including, but not limited to: Milankovitch cycles, era, epoch, period, parent isotope, hot spot, paleomagnetism, and index fossil	
	D2.2	Use a research process to investigate the geological history of an area in Ontario (e.g., sequence diagrams, geological maps or associated rock types, and/or surficial/bedrock geology maps)	
	D2.3	Investigate various types of preserved geological evidence of major changes that have taken place in Earth history (e.g., fossils, topographic evidence of past glaciations, evidence of plate movement in igneous rocks with magnetic reversals)	
	D2.5	Produce diagrams to illustrate the development of various types of unconformities preserved in a sequence of strata (e.g., angular unconformity, disconformity, nonconformity)	
	D2.6	Design and build a model to represent radioactive decay and the concept of half-life determination	
	D2.7	Investigate interactions over time between physical, chemical, and biological processes, and explain how they have affected environmental conditions throughout Earth's geological history	

SES4U			
D3	Demonstrate an understanding of how changes to Earth's surface have been recorded and preserved throughout geological time and how they contribute to our knowledge of Earth's history		Mission planning. Training for and carrying out geological and geographical measurements during mission activities. Planning, designing, and construction of planetary surface and specific features and collectables to be integrated into the surface as well as features to integrate into the simulated environment.
	D3.3	Describe some processes by which fossils are produced and/or preserved (e.g., original preservation, carbonization, replacement, permineralization, mould and cast formations)	
	D3.4	Compare and contrast relative and absolute dating principles and techniques as they apply to natural systems (e.g., the law of superposition; the law of cross-cutting relationships; varve counts; carbon-14 or uranium-lead dating)	
	D3.5	Identify and describe the various methods of isotopic age determination, giving for each the name of the isotope, its half-life, its effective dating range, and some of the materials that it can be used to date (e.g., uranium-lead dating of rocks; carbon dating of organic materials)	
	D3.6	Explain the influence of paradigm shifts (e.g., from uniformitarianism to catastrophism) in the development of geological thinking	
	D3.7	Explain the different types of evidence used to determine the age of Earth (e.g., index fossils; evidence provided by radiometric dating of geological materials or lithostratigraphy) and how this evidence has influenced our understanding of the age of the planet	

E: Earth Materials			
E2	Investigate the properties of minerals and characteristics of rocks, including those in their local area		Planning for and fabrication of the planetary surface. Astronaut training to map out, describe, and interpret the planetary surface. Astronauts also must be trained to conduct tests such as streak and hardness testing. Design of real, simulated, or virtual technology to carry out tests and analysis or planetary samples.
	E2.1	Use appropriate terminology related to Earth materials, including, but not limited to: geothermal vents, porosity, permeability, cleavage, fracture, cementation, evaporite, and foliation	
	E2.2	Investigate the properties of materials (e.g., density, conductivity, porosity; magnetic properties; radioactivity), explain how they affect usage, and what technologies and techniques are used to explore for or extract them (e.g., radiometric instruments, electromagnetic or gravity surveys)	
	E2.3	Conduct tests (e.g., hardness, streak, density) to identify and classify common minerals (e.g., quartz, calcite, feldspars, micas, graphite, hornblende)	
	E2.4	Ivestigate common igneous rocks (e.g., granite, andesite, basalt, gabbro), using a hand lens, classify based on texture (e.g., porphyritic, phaneritic, aphanitic) and composition (e.g., acid, intermediate, basic), to determine origins (i.e., extrusive or intrusive)	
	E2.5	Investigate sedimentary rocks (e.g., conglomerate, breccia, sandstone, shale, limestone, coal), using a hand lens, classify based on texture (e.g., coarse- or fine-grained, detrital) and composition (e.g., clastic, chemical, fossil inclusions), to determine their origin (e.g., clastic, chemical)	
	E2.6	Investigate metamorphic rocks (e.g., slate, phyllite, schist, gneiss, quartzite), using a hand lens, classify based on characteristics (e.g., foliation, crystallinity) in order to identify their parent rock and the temperature, pressure, and chemical conditions at their formation	
	E2.7	Investigate a geological setting in their local area (e.g., a river/stream bed or lakeshore; a rock outcrop), and identify and classify rock samples collected	
	E2.8	Plan and conduct an inquiry to investigate the factors that determine the size and form of mineral crystals (e.g., solution temperature, the salt type, level of saturation, the temperature of slides of melted salol)	

<table>
<tr><td colspan="4">SES4U</td></tr>
<tr><td rowspan="5">E3</td><td colspan="3">Demonstrate an understanding of the properties of minerals and the formation and characteristics of rocks</td></tr>
<tr><td>E3.1</td><td>Identify the physical and chemical properties of selected minerals, and describe the tests used to determine these properties</td><td>Research to integrate the proper samples into the planetary surface by simulators. Analysis or planetary surface samples.</td></tr>
<tr><td>E3.2</td><td>Describe the formation (i.e., intrusive or extrusive) and identify the distinguishing characteristics of igneous rocks (e.g., composition and eruption type; mineralogical content indicating the type of volcano in which a rock was formed)</td><td rowspan="3">Astronauts and mission control staff require training to links rock and mineral description and identification to specific geological interpretations in order to address mission research goals.

Simulators require the same training in order to fabricate a planetary surface and virtual environment in order to recreate scenarios appropriate to the mission destination and the general goals set out my by the membership.</td></tr>
<tr><td>E3.3</td><td>Describe the formation of clastic and chemical sediments, and the characteristics of the corresponding sedimentary rocks (e.g., shape and size of particles, nature of their deposition)</td></tr>
<tr><td>E3.4</td><td>Describe the different ways in which metamorphic rocks are formed (i.e., through changes in temperature, pressure, and chemical conditions) and the factors that contribute to their variety (e.g., variation in parent rock; regional or contact metamorphism)</td></tr>
<tr><td colspan="4">F: Geological Processes</td></tr>
<tr><td rowspan="8">F2</td><td colspan="3">Investigate (using models and analysis of information gathered from various sources) the nature of internal and surficial Earth processes, and how these processes can be quantified</td></tr>
<tr><td>F2.1</td><td>Use appropriate terminology related to geological processes, including, but not limited to: shear forces, compression forces, liquifaction, Benioff zone, aquifer, internal plastic flow, basal slip, mid-oceanic ridge, bedding, cross-cutting, isostasy, and lithification</td><td rowspan="3">Making a plan for the planetary surface features and fabricate them.

Training for the analysis of fabricated features by the astronauts and mission control backup science team.</td></tr>
<tr><td>F2.2</td><td>Investigate the difference between weathering and erosion and construct models of the processes of physical, chemical, and biological weathering (e.g., water dripping on a bar of soap; vinegar dripping on a marble chip)</td></tr>
<tr><td>F2.3</td><td>Produce a model showing simple sedimentary sequences (e.g., successive layering, sorted sequences), using block diagrams or three-dimensional models (e.g., layering as sand settles in an aquarium)</td></tr>
<tr><td>F2.4</td><td>Investigate, through laboratory inquiry or computer simulation, the main types of seismic waves, and produce a model (e.g., using 3D block diagrams or springs and ropes) to illustrate for each the nature of its propagation, the transfer of energy, and its movement through rocks</td><td>Analyse and interpret information from simulated seismic instruments to assess both the nature of the planetary substructure as well as any risks to the astronauts and spacecraft.</td></tr>
<tr><td>F2.5</td><td>Locate the epicentre of an earthquake, given the appropriate seismographic data (e.g., the travel-time curves to three recording stations for a single event)</td><td>Analyse and interpret information from simulated seismic instruments using both natural seismic events and seismic charges to assess the nature of the planetary substructure</td></tr>
<tr><td>F2.6</td><td>Produce a scale model (e.g., a 3D block diagram) of the interior of Earth, differentiating between the layers and their characteristics (e.g., label cross-sections with the dimensions of the crust, mantle, and inner and outer core, and add travel-time curves for various seismic waves to provide data on the characteristics of the individual layers)</td><td>Use the results of simulated seismic information as well as gravity, magnetic, and radiation surveys and radar tomography from orbit to reconstruct the internal structure of the planetary body.</td></tr>
<tr><td>F2.8</td><td>Analyse information from a plan view (e.g., topographic map, air photo, geologic map) and sectional view (e.g., cross section, block diagram) in order to deduce the geologic history of an area</td><td>Reconstruct the structure and history of the planetary destination.</td></tr>
</table>

SES4U			
F3	Demonstrate an understanding of the processes at work within Earth and on its surface, and the role of these processes in shaping Earth's surface		
	F3.1	Describe boundaries (convergent, divergent, transform) between lithospheric plates, and explain the internal Earth processes occurring at each (e.g., subduction, divergence, convergence, hot spots, folding, faulting)	Making a plan for the planetary surface features and fabricate them. Training for the analysis of fabricated features by the astronauts and mission control backup science team.
	F3.2	Describe the characteristics of the main types of seismic waves (i.e., P- and S-waves; R- and L-waves), and explain the different modes of travel, travel times, and types of motion associated with each	Training for assessment of seismic risks to the spacecraft. Research by the simulators to produce sensible seismic events for the mission.
	F3.3	Compare qualitative and quantitative methods used to measure earthquake intensity and magnitude (e.g., the Mercalli Scale, the Richter Scale)	
	F3.4	Explain how different erosional processes contribute to changing landscapes (e.g., channel erosion)	Making a plan for the planetary surface features and fabricate them. Training for the analysis of fabricated features by the astronauts and mission control backup science team.
	F3.5	Identify and describe types of sediment transport (e.g., water, wind, glacial) and the types of load (i.e., dissolved load, suspended load, bed load) as sediment is moved by each type of transport	
	F3.6	Describe landforms made by water, wind, or ice erosion	
	F3.7	Describe the sedimentary structures formed by wind, water, or ice deposition	
	F3.8	Identify major areas of tectonic activity in the world by plotting the location of major recorded earthquakes and active volcanoes on a map, and distinguish the areas by type of tectonic activity	Reconstruct the structure and history of the planetary destination.

<table>
<tr><td colspan="4">Physics SPH3U</td></tr>
<tr><td colspan="4">A: Scientific Investigation Skills and Career Exploration</td></tr>
<tr><td>A1</td><td colspan="2">Demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating)</td><td>See SCH3U</td></tr>
<tr><td colspan="4">B: Kinematics</td></tr>
<tr><td rowspan="8">B2</td><td colspan="3">Investigate, in qualitative and quantitative terms, uniform and non-uniform linear motion, and solve related problems</td></tr>
<tr><td>B2.1</td><td>Use appropriate terminology related to kinematics, including, but not limited to: time, distance, position, displacement, speed, velocity, and acceleration</td><td>Piloting.
Piloting training (see B2.5).</td></tr>
<tr><td>B2.4</td><td>Conduct an inquiry into the uniform and non-uniform linear motion of an object (e.g., use probeware to record the motion of a cart moving at a constant velocity or a constant acceleration; view a computer simulation of an object attaining terminal velocity; observe a video of a bouncing ball or a skydiver; observe the motion of a balloon with a small mass suspended from it)</td><td>Piloting,
Piloting training (see B2.5).
Recording flight tracks on mission control software.</td></tr>
<tr><td>B2.5</td><td>Solve problems involving distance, position, and displacement (e.g., find total displacement using a scale vector diagram and vector components, and compare it to total distance travelled)</td><td rowspan="9">Mission profile development (such as course correction, orbit transition manoeuvers, intercept planning, docking with main drive unit).

Launch abort planning.

Trainees are given specific components of a mission to practice (such as lift off to orbit) then given parts of the procedure to vary to see how these variances affect the outcome of the procedure. They are asked questions about what the significance of these variations are for the success of the procedure and for dealing with malfunctions and other incidents (such as how carrying more fuel affects the path to orbit and the consequences of an engine loss during ascent to orbit).</td></tr>
<tr><td>B2.6</td><td>Plan and conduct an inquiry into the motion of objects in one dimension, using vector diagrams and uniform acceleration equations</td></tr>
<tr><td>B2.7</td><td>Solve problems involving uniform and non-uniform linear motion in one and two dimensions, using graphical analysis and algebraic equations</td></tr>
<tr><td>B2.8</td><td>Use kinematic equations to solve problems related to the horizontal and vertical components of the motion of a projectile</td></tr>
<tr><td>B2.9</td><td>Conduct an inquiry into the projectile motion of an object, and analyse, in qualitative and quantitative terms, the relationship between the horizontal and vertical components (e.g., airborne time, range, maximum height, horizontal velocity, vertical velocity)</td></tr>
<tr><td rowspan="4">B3</td><td colspan="2">Demonstrate an understanding of uniform and non-uniform linear motion, in one and two dimensions</td></tr>
<tr><td>B3.1</td><td>Distinguish between the terms constant, instantaneous, and average with reference to speed, velocity, and acceleration, and provide examples to illustrate each term</td></tr>
<tr><td>B3.2</td><td>Distinguish between, and provide examples of, scalar and vector quantities as they relate to the description of uniform and non-uniform linear motion (e.g., time, distance, position, velocity, acceleration)</td></tr>
<tr><td>B3.3</td><td>Describe the characteristics and give examples of a projectile's motion in vertical and horizontal planes</td></tr>
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<table>
<tr><td colspan="4">SPH3U</td></tr>
<tr><td colspan="4">C: Forces</td></tr>
<tr><td>C1</td><td colspan="2">Analyse and propose improvements to technologies that apply concepts related to dynamics and Newton's laws, and assess the technologies' social and environmental impact</td><td rowspan="2">EEP presentation 1</td></tr>
<tr><td></td><td>C1.1</td><td>Analyse, with reference to Newton's laws, a technology that applies these laws (e.g., extremely low friction bearings, near frictionless carbon, different types of athletic shoes, roller coasters), and propose ways to improve its performance</td></tr>
<tr><td rowspan="7">C2</td><td colspan="3">Investigate, in qualitative and quantitative terms, net force, acceleration, and mass, and solve related problems</td></tr>
<tr><td>C2.1</td><td>Use appropriate terminology related to forces, including, but not limited to: mass, time, speed, velocity, acceleration, friction, gravity, normal force, and free-body diagrams</td><td rowspan="6">(see also B2.5)

Mission profile development (such as course correction, orbit transition manoeuvers, intercept planning, docking with main drive unit).

For example:
Students learn how to minimize fuel use and braking acceleration while landing through an atmosphere by utilizing atmospheric drag forces as well as atmospheric lift to prolong the period of time spend braking in the lower density upper parts of the atmosphere.

Students learn how to balances the forces on the spacecraft to keep it in a hover above the landing pad and carefully shift its position to land correctly.

Students learn the difference between acceleration and velocity by applying a force to accelerate the spacecraft from a hover into a sideways drift and when to apply an opposing acceleration so as to bring the drift velocity to zero at the correct position above the landing pad.

Students learn the tradeoffs between safety in a low speed descent with braking thrust to a zero descent at touch down and minimizing the fuel use with a high speed descent to touch down with less time but higher thrust levels and more critical adjustment timing.</td></tr>
<tr><td>C2.2</td><td>Conduct an inquiry that applies Newton's laws to analyse, in qualitative and quantitative terms, the forces acting on an object, and use free-body diagrams to determine the net force and the acceleration of the object</td></tr>
<tr><td>C2.3</td><td>Conduct an inquiry into the relationship between the acceleration of an object and its net force and mass (e.g., view a computer simulation of an object attaining terminal velocity; observe the motion of an object subject to friction; use electronic probes to observe the motion of an object being pulled across the floor), and analyse the resulting data</td></tr>
<tr><td>C2.4</td><td>Analyse the relationships between acceleration and applied forces such as the force of gravity, normal force, force of friction, coefficient of static friction, and coefficient of kinetic friction, and solve related problems involving forces in one dimension, using free-body diagrams and algebraic equations (e.g., use a drag sled to find the coefficient of friction between two surfaces)</td></tr>
<tr><td>C2.5</td><td>Plan and conduct an inquiry to analyse the effect of forces acting on objects in one dimension, using vector diagrams, free-body diagrams, and Newton's laws</td></tr>
<tr><td>C2.6</td><td>Analyse and solve problems involving the relationship between the force of gravity and acceleration for objects in free fall</td></tr>
<tr><td rowspan="4">C3</td><td colspan="3">Demonstrate an understanding of the relationship between changes in velocity and unbalanced forces in one dimension</td></tr>
<tr><td>C3.1</td><td>Distinguish between, and provide examples of, different forces (e.g., friction, gravity, normal force), and describe the effect of each type of force on the velocity of an object</td><td rowspan="3">(see also C2)

Mission profile development (such as course correction, orbit transition manoeuvers, intercept planning, docking with main drive unit).</td></tr>
<tr><td>C3.3</td><td>State Newton's laws, and apply them, in qualitative terms, to explain the effect of forces acting on objects</td></tr>
<tr><td>C3.4</td><td>Describe, in qualitative and quantitative terms, the relationships between mass, gravitational field strength, and force of gravity</td></tr>
</table>

SPH3U			
D: Energy and Society			
D1	Analyse technologies that apply principles of and concepts related to energy transformations, and assess the technologies' social and environmental impact		
	D1.1	Analyse, using the principles of energy transformations, a technology that involves the transfer and transformation of thermal energy (e.g., a power station, an air conditioner, a fuel cell, a laser printer)	EPDS training and management during mission activities.
D2	Investigate energy transformations and the law of conservation of energy, and solve related problems		
	D2.1	Use appropriate terminology related to energy transformations, including, but not limited to: mechanical energy, gravitational potential energy, kinetic energy, work, power, fission, fusion, heat, heat capacity, temperature, and latent heat	Pilot training involving an understanding of the transformation of kinetic and gravitational potential energy in transfer orbits and other orbital manoeuvers.
	D2.4	Plan and conduct inquiries involving transformations between gravitational potential energy and kinetic energy (e.g., using a pendulum, a falling ball, an object rolling down a ramp) to test the law of conservation of energy	
	D2.5	Solve problems involving the relationship between power, energy, and time	EPDS fuel management.. Includes considerations of the efficiency of different electrical power generation systems on the spacecraft and the ability of different generator types to meet the power needs of certain loads (e.g., engines, magnetic radiation shielding).
	D2.6	Conduct inquiries and solve problems involving the relationship between power and work (e.g., the power of a student using different types of fitness equipment)	
	D2.7	Compare and contrast the input energy, useful output energy, and per cent efficiency of selected energy generation methods (e.g.,hydroelectric, thermal, geothermal, nuclear fission, nuclear fusion, wind, solar)	
D3	Demonstrate an understanding of work, efficiency, power, gravitational potential energy, kinetic energy, nuclear energy, and thermal energy and its transfer (heat)		
	D3.1	Describe a variety of energy transfers and transformations, and explain them using the law of conservation of energy	see SPH3U section D2
	D3.2	Explain the concepts of and interrelationships between energy, work, and power, and identify and describe their related units	
	D3.3	Explain the following concepts, giving examples of each, and identify their related units: thermal energy, kinetic energy, gravitational potential energy, heat, specific heat capacity, specific latent heat, power, and efficiency	
	D3.6	Describe and compare nuclear fission and nuclear fusion	EPDS reactor control and exhaust management.
	D3.9	Identify and describe the structure of common nuclear isotopes (e.g., hydrogen, deuterium, tritium)	
	D3.10	Compare the characteristics of (e.g., mass, charge, speed, penetrating power, ionizing ability) and safety precautions related to alpha particles, beta particles, and gamma rays	EECOM radiation management system. Astronauts, mission control, and simulators must be familiar with radiation types, shielding, dose rates and their effects.

SPH3U			
F: Electricity and Magnetism			
F2	Investigate, in qualitative and quantitative terms, magnetic fields and electric circuits, and solve related problems		
	F2.1	Use appropriate terminology related to electricity and magnetism, including, but not limited to: direct current, alternating current, conventional current, electron flow, electrical potential difference, electrical resistance, power, energy, step-up transformer, and step-down transformer	Software development for electrical power distribution system (EPDS). Management of EPDS during mission.
	F2.2	Analyse diagrams of series, parallel, and mixed circuits with reference to Ohm's law (V = IR) and Kirchhoff's laws	
	F2.3	Design and build real or computer-simulated mixed direct current (DC) circuits, and explain the circuits with reference to direct current, potential difference, and resistance	Construction of auxiliary communication systems, door sensor circuits, control panels, and mock control circuits.
	F2.8	Construct a prototype of a device that uses the principles of electromagnetism (e.g., an electric bell, loudspeaker, ammeter, electric motor, electric generator), and test and refine their device	

<table>
<tr><td colspan="4">Physics SPH4U</td></tr>
<tr><td colspan="4">A: Scientific Investigation Skills and Career Exploration</td></tr>
<tr><td>A1</td><td colspan="2">Demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating)</td><td>see SCH3U</td></tr>
<tr><td rowspan="2">A2</td><td colspan="3">Identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields</td></tr>
<tr><td>A2.1</td><td>Identify and describe a variety of careers related to the fields of science under study (e.g., laser optics researcher, geoscientist, photonics researcher, aerospace engineer) and the education and training necessary for these careers</td><td>Members work with partner organisations: Let’s Talk Science, Planetary Society, Canadian Space Society , etc.</td></tr>
<tr><td colspan="4">B: Dynamics</td></tr>
<tr><td rowspan="3">B1</td><td colspan="3">Analyse technological devices that apply the principles of the dynamics of motion, and assess the technologies' social and environmental impact</td></tr>
<tr><td>B1.1</td><td>Analyse a technological device that applies the principles of linear or circular motion (e.g., a slingshot, a rocket launcher, a race car, a trebuchet)</td><td>Piloting training.
Orbit software development.</td></tr>
<tr><td>B1.2</td><td>Assess the impact on society and the environment of technological devices that use linear or circular motion (e.g., projectile weapons, centrifuges, elevators)</td><td>Mission planning.
Work with partner organisations.</td></tr>
<tr><td rowspan="4">B2</td><td colspan="3">Investigate, in qualitative and quantitative terms, forces involved in uniform circular motion and motion in a plane, and solve related problems</td></tr>
<tr><td>B2.1</td><td>Use appropriate terminology related to dynamics, including, but not limited to: inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction, and kinetic friction</td><td rowspan="3">Piloting training (see also SPH3U B2.5).
Students learn how to orient the spacecraft to apply thrust to alter orbital trajectory with the least fuel use and fewest orientation changes.
Students learn that all velocity and distance measurements must be made relative to some centre of reference. Velocity and displacement also must be considered as separate components. Students must be able to work with both X/Y components as well as angular/ distance components or displacement and centripetal/tangential components of velocity. Students must learn to anticipate how the components of displacement and velocity will change when transitioning from one centre of reference to another.
Alterations to an orbit typically involve reducing the relative velocity in one component while increasing it in another. It is easier and safer to do both simultaneously with the correct thrust vector.</td></tr>
<tr><td>B2.2</td><td>Solve problems related to motion, including projectile and relative motion, by adding and subtracting two-dimensional vector quantities, using vector diagrams, vector components, and algebraic methods</td></tr>
<tr><td>B2.7</td><td>Conduct inquiries into the uniform circular motion of an object (e.g., using video analysis of an amusement park ride,), and analyse, in qualitative and quantitative terms, the relationships between centripetal acceleration, centripetal force, radius of orbit, period, frequency, mass, and speed</td></tr>
<tr><td rowspan="2">B3</td><td colspan="3">Demonstrate an understanding of the forces involved in uniform circular motion and motion in a plane</td></tr>
<tr><td>B3.2</td><td>Explain the advantages and disadvantages of static and kinetic friction in situations involving various planes (e.g., a horizontal plane, a variety of inclined planes)</td><td>EEP presentation 1,2.
Piloting training.</td></tr>
</table>

<table>
<tr><td colspan="4">SPH4U</td></tr>
<tr><td colspan="4">C: Energy and Momentum</td></tr>
<tr><td rowspan="2">C1</td><td colspan="3">Analyse, and propose ways to improve, technologies or procedures that apply principles related to energy and momentum, and assess the social and environmental impact of these technologies or procedures</td></tr>
<tr><td>C1.1</td><td>Analyse, with reference to the principles of energy and momentum, and propose practical ways to improve, a technology or procedure that applies these principles (e.g., fireworks, rocket propulsion, protective equipment, forensic analysis of vehicle crashes, demolition of buildings)</td><td>Development of launch, landing, and orbit procedures and subsequent training.

Students look at departures from ideal Hohmann transfer orbits and how each one increases or decreases the total amount of fuel used relative to other factors such as duration and the change in speed needed to enter orbit at the destination.</td></tr>
<tr><td rowspan="5">C2</td><td colspan="3">Investigate, in qualitative and quantitative terms, through laboratory inquiry or computer simulation, the relationship between the laws of conservation of energy and conservation of momentum, and solve related problems</td></tr>
<tr><td>C2.1</td><td>Use appropriate terminology related to energy and momentum, including, but not limited to: work, work-energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum-impulse theorem, elastic collision, and inelastic collision</td><td rowspan="4">Piloting training.
EEP presentation 1,2.

Students learn that the total energy of an orbiting spacecraft is constant, but that the gravitational potential energy and the kinetic energy of the spacecraft change antagonistically as the altitude of the spacecraft changes.

Students learn that the spacecraft can have drastically different energies in reference to different celestial objects.

Students learn the effect of thrust and duration on the change in velocity of the spacecraft.

The learn the difference between an unstable orbit and an non-circular obit. They learn how different thrust angles alter the kinetic energy and the path of a spacecraft in orbit in dramatically different ways.</td></tr>
<tr><td>C2.2</td><td>Analyse, in qualitative and quantitative terms, the relationship between work and energy, using the work-energy theorem and the law of conservation of energy, and solve related problems in one and two dimensions</td></tr>
<tr><td>C2.3</td><td>Use an inquiry process to analyse, in qualitative and quantitative terms, situations involving work, gravitational potential energy, kinetic energy, thermal energy, and elastic potential energy, in one and two dimensions (e.g., a block sliding along an inclined plane with friction; a cart rising and falling on a roller coaster track; an object, such as a mass attached to a spring pendulum, that undergoes simple harmonic motion), and use the law of conservation of energy to solve related problems</td></tr>
<tr><td>C2.4</td><td>Conduct a laboratory inquiry or computer simulation to test the law of conservation of energy during energy transformations that involve gravitational potential energy, kinetic energy, thermal energy, and elastic potential energy (e.g., using a bouncing ball, a simple pendulum, a computer simulation of a bungee jump)</td></tr>
<tr><td colspan="4">F: Revolutions in Modern Physics: Quantum Mechanics and Special Relativity</td></tr>
<tr><td rowspan="2">F1</td><td colspan="2">Analyse, with reference to quantum mechanics and relativity, how the introduction of new conceptual models and theories can influence and/or change scientific thought and lead to the development of new technologies</td><td rowspan="4">Software development of orbit software with respect to relativistic limitations on the motion of the spacecraft.

Mission planning for especially long-duration high-speed mission profiles.</td></tr>
<tr><td>F1.2</td><td>Assess the importance of relativity and quantum mechanics to the development of various technologies (e.g., nuclear power; light sensors; diagnostic tools such as magnetic resonance imaging [MRI], computerized axial tomography [CAT])</td></tr>
<tr><td rowspan="2">F2</td><td colspan="2">Investigate special relativity and quantum mechanics, and solve related problems</td></tr>
<tr><td>F2.3</td><td>Solve problems related to Einstein's theory of special relativity in order to calculate the effects of relativistic motion on time, length, and mass (e.g., how far into the future a fast space ship would travel)</td></tr>
</table>

Digital Imagery and Web Design TGJ4O			
A: COMMUNICATIONS TECHNOLOGY FUNDAMENTALS			
A1	Demonstrate understanding of core concepts, techniques, and skills needed to produce a range of photographic, digital imaging, animation, 3D modelling, and/or web design products or services		
	A1.2	Use photographic, imaging, and computer equipment safely and correctly to perform basic production tasks or create simple products (e.g., set up cameras, tripods, and lights; capture images with a digital camera or scanner; transfer images between devices)	A spacesim web page and wiki page are maintained by the organization. Management of these pages is the responsibility of a web master, but all members are encouraged to contribute to the wiki, following templates and other guidelines. The web master also controls the spacesim email system and monitors the various spacesim facebook pages. Both the website and the email system are portals for community groups to inquire about services offered by the organisation.
	A1.3	Use imaging, image editing, animation, 3D modeling, and web design software correctly to perform basic production tasks or create simple products (e.g., correcting and manipulating images, preparing images for web or print viewing, tweening, texture mapping, creating an animated GIF, designing a web page)	
	A1.4	Demonstrate an understanding of the creative skills and techniques required to produce effective photographs, digital images, animations, 3D models, and/or web pages (e.g., composition, lighting, image editing and optimization, claymation, site planning)	
	A1.7	Apply basic design principles (balance, rhythm, proportion, flow) and elements (colour, line, space, form, texture) to communicate an idea or concept.	
A3	Demonstrate an understanding of and apply the interpersonal skills necessary to work effectively with clients and peers		
	A3.1	Explain the value of sharing ideas, information, resources, and expertise when working in a team setting	Club meetings follow a set of procedures designed to ensure that all members have an opportunity to voice concerns and thoughts. Setting up of task forces to handle specific aspects of mission preparation. Task force activities often take place in multiple locations simultaneously, thus requiring co-ordination between members. Procedures and ideas are written up in wiki pages following established templates. Training sessions lead by member experts take place regularly during work sessions to ensure that corporate knowledge is passed along to less experienced members and so that all members feel comfortable in carrying out mission critical procedures.
	A3.2	Describe and use techniques that encourage participation by all members of a team (e.g., brainstorming, group discussion, celebration of others' thoughts or contributions)	
	A3.3	Describe and use concepts and techniques that facilitate effective collaboration in a team environment (e.g., cooperative discussion, conflict resolution techniques, motivation techniques, respect for the ideas of others, constructive criticism)	

Communications Technology TGJ2O			
A. COMMUNICATIONS TECHNOLOGY FUNDAMENTALS			
A3	Demonstrate an understanding of and apply the interpersonal and communication skills necessary to work effectively in a team setting.		Each year, the capsule communication system and EVA communications systems must be maintained and upgraded. In some years, this process involves a complete overhaul of the communications system. This system involves several types of communications: 1) between EVA astronauts and the spacecraft control room (audio) 2) within compartments of the spacecraft (audio and video) 3) between the spacecraft and mission control (with interception by simulators) (audio, video, and text) which must be ported over the VPN connection between the two locations; each side must be able to select between multiple video channels
	A3.1	Explain the value of sharing ideas, information, resources, and expertise when working in a team setting	
	A3.2	Describe and use techniques that encourage participation by all members of a team (e.g., brainstorming, group discussion, celebration of others' thoughts or contributions, acceptance of cultural differences)	
	A3.3	Describe and use concepts and techniques that facilitate effective collaboration in a team environment (e.g., cooperative discussion, conflict resolution techniques, motivation techniques, respect for the ideas of others)	

Construction Technology TCJ2O			
A. CONSTRUCTION TECHNOLOGY FUNDAMENTALS			
A1	Describe the components and systems of buildings, the properties of various building materials, and the processes in which those materials are used		
	A1.1	Identify the different components of a residential construction project (e.g., footings, foundation, joists, studs, trusses, rafters, millwork, trim, cabinetry), and outline the sequence in which these components are usually installed	Understand the structural components of the spacecraft mockup and how to make modifications to the spacecraft so as not to undermine the structural integrity. Understand how ancillary components (cabinets, shelves, mockup components etc,) are integrated into the main structure.
	A1.2	Identify the various systems in a building (e.g., foundation, framing, electrical, plumbing, cabinetry), and describe their functions	Understand how the plumbing, mains electrical, and low-voltage wiring is integrated into the framing of the spacecraft.
	A1.3	Identify natural and manufactured building materials and products commonly used in the construction industry, and describe their specifications and characteristics (e.g., natural wood: species, source, nominal and actual dimensions, grade; plywood, metals, plastics: type, grade, resistance to weather or corrosion)	Understand why the different construction materials (steel studs, drywall, plywood, particle board) are chosen with respect to carrying out the purpose of the feature (in terms of the actual structure and how it works as an analogue structure within the simulation activity), safety considerations, and how the material mimics the analogous material in a real spacecraft.
	A1.5	List the steps of the processes used in a construction project (e.g., woodworking: planing, shaping, sanding; framing: installing sill plates, laying out floor joists, installing subfloor)	Students formulate plans to submit to the teacher advisor for the construction of spacecraft and planetary surface components. Once approved, each step in the construction process is checked and approved before carrying on with the next.
	A1.6	Describe various processes and materials used to finish surfaces in construction projects (e.g., applying primers, sealers, stains, varnishes, paints, veneers, laminates, and siding)	Students must understand the finishing requirements of different construction materials and the requirements for each type of finishing to properly adhere.
A2	Demonstrate an understanding of the safe and correct use of construction tools, equipment, and techniques		
	A2.1	Explain how to correctly and safely use, maintain, and store construction tools and equipment (e.g., hammers, measuring instruments, table saws, mitre saws, drills, lathes, cordless drills)	Students must be trained and demonstrate an understanding of how each type of tool is to be used to: work safely, accomplish the desired task, and avoid damaging the tools. Tool selection is one of the components of each plan that must be checked by the teacher advisor.
	A2.2	Select the most appropriate tools or equipment for specific tasks (e.g., wooden mallet versus framing hammer, crosscut saw versus rip saw, combination square versus framing square)	
	A2.3	Describe commonly used layout, measuring, and tracing techniques (e.g., determining and marking circumference, diameter, radius, angles, rounded corners)	Students are taught proper methods and tools for measurement in different circumstances. Proficiency is evaluated as part of the initial implementation of each project.
	A2.4	Describe commonly used temporary and permanent assembly techniques (e.g., temporary: using screws or double-headed nails; permanent: gluing with butt, mortise and tenon, dovetail, or mitre joints)	Specification of assembly techniques is one of the components of each plan that must be checked by the teacher advisor. Proper implementation of each technique us part of the training and evaluation of work completed.
A3	Use correct terminology to describe building components and construction materials, tools, equipment, and processes		
	A3.1	Use correct terminology for the names, characteristics, and functions of construction materials, tools, and equipment in oral and written communication (e.g., reports, lists of tools and materials, schedules, design presentations)	Students are encouraged to use industry standard terminology so as to better perform in construction work carried out outside of the group.
	A3.2	Use correct terminology to describe building components and construction processes (e.g., components: header, lintel; processes: levelling, squaring, making plumb)	

TCJ2O		
B. DESIGN, LAYOUT, AND PLANNING SKILLS		
B1	Design construction projects, individually or in small groups, applying a design process to plan and develop the projects and other problem-solving processes to address various related problems and challenges	
B1.1	Follow the steps of a design process to plan and develop a construction project (e.g., analyse the situation or context; identify the need or problem; generate solutions to address the need; conduct research to determine constraints and availability of materials; build a model; test the model; modify the design as necessary; build the project according to the final design)	Task forces for construction projects are required to justify the plans with respect to issues of functionality, ease of maintenance, safety, and longevity.
B1.2	Use appropriate problem-solving processes and techniques to address various specific problems or challenges that may arise in connection with a construction project	Students work in task forces to develop procedures for solving construction-related problems. These are evaluated and commented upon by the teacher advisor.
B1.4	Use appropriate design elements and principles (e.g., elements: line, shape, direction, space, texture, colour; principles: balance, scale, proportion, contrast, unity) to enhance the appearance and functionality of construction projects	Construction plans are tailored to meet the requirement of simulating structures in a real spacecraft and the special needs of working in an environment that can experience variation in atmospheric pressure and acceleration.
B1.5	Identify standards, regulations, and building codes that affect the design, layout, and details of construction projects (e.g., spacing of studs in a wall, incline on access ramps, heights of counters and furniture)	Students are given information of building codes and shown how the plans that they develop for modifications and original constructions can be made to conform to the codes. The rational for the codes also are explained so that students understand why knowledge of them and adherence to them is important both within the group's projects and outside of the group.
B2	Use drawings to represent design ideas and solutions to technological challenges, and interpret drawings accurately when working on construction projects	
B2.1	Produce sketches, technical drawings, and detail drawings to represent design ideas and solutions for a variety of construction projects	Task forces are required to draw up plans that could be followed by another task force with different members if needed.
B2.2	Identify basic drawing conventions used in construction drawings (e.g., scales, metric and imperial dimensioning, notes, views, line types, symbols, abbreviations)	
B2.3	Interpret technical drawings accurately when working on construction projects (e.g., determine dimensions and materials from a drawing)	
B3	Apply the mathematical skills required in the planning and building of construction projects	
B3.1	Apply relevant mathematical concepts and formulas when preparing components of a construction project (e.g., determine dimensions, shapes, quantities, areas, and angles)	Plans and drawings must be made careful analysis of the dimensions of all components. All measurements are made with industry standard units where necessary so as to make purchasing the correct materials possible.
B3.2	Convert fractions to decimals and vice versa for typical construction tasks (e.g., determining length, circumference, radius, diameter, perimeter, area, or volume)	
B3.3	Use appropriate metric and imperial approximations for sizes commonly used in the construction industry (e.g., 1/8 inch=3 mm), and find equivalents for measurements when required, using appropriate charts and tables	
B3.4	Determine lengths and diameters of fastening devices needed to assemble various construction projects (e.g., lengths and gauges of screws, nails, and staples; diameters of dowels), using appropriate metric and/or imperial units	
B3.5	Prepare estimates, using appropriate metric and/or imperial units (e.g., centimetres, square metres, cubic metres, litres, inches, board feet, square feet, cubic yards), of the materials required to complete construction projects (e.g., volume of concrete, area of roofing, number and type of fasteners), and estimate the cost of these materials	These are required from each task force project so that the ability to carry out the plan within the set budget can be ascertained. Lists of materials also are necessary so that all materials can be obtained prior to commencement of the project.

TCJ2O			
C: FABRICATION, ASSEMBLY, AND FINISHING SKILLS			
C1	Use tools, equipment, and techniques correctly and safely when preparing materials for a project		
	C1.1	Use tools, equipment, and techniques in a correct, efficient, and safe manner to prepare project materials (e.g., dress raw lumber; measure, cut, and square stock; drill; fasten and join)	Students are trained and evaluated on the proficiency with which carry out safe use of tools and the making of accurate measurements. Tool use permissions are graduated with respect to the safety concerns inherent in the tools so that students demonstrate reliable adherence to safety practices prior to use of more dangerous tools.
	C1.2	Perform the various measurements required in the fabrication and assembly of a project, using appropriate metric and imperial units	
C2	Use fabrication and assembly techniques safely, accurately, and in the correct sequence		
	C2.1	Construct projects in accordance with specifications (e.g., sketches, working drawings, lists of materials)	Task forces are checked for adherence to the procedures specified in the project plans. Evaluation of completed steps is made before proceeding to subsequent steps. A dictum of disposal of material rather than making do with unsatisfactory procedures is followed.
	C2.2	Fabricate and/or assemble project components in a logical and efficient sequence (e.g., select appropriate materials and tools, follow step-by-step instructions)	
	C2.3	Apply appropriate quality-control measures to ensure precise dimensions and correct assembly (e.g., accurate cuts, clean joints, true edges)	
C3	Prepare surfaces and apply finishing products, trim, and hardware correctly and safely		
	C3.1	Prepare surfaces correctly for finish application according to type of material, desired finish, and intended use of the project (e.g., wood species used, smooth or textured surface, environment to which surface is exposed)	Fresh and old surfaces are properly treated so as to allow finishing material to properly adhere. Manufacturer's instructions are followed. Processes that use consumables efficiently are followed. Materials are applied or attached such as to make the product fit properly into the simulation process.
	C3.2	Apply suitable finishes (e.g., stain, paint, varnish, oil, wax), taking into account the type of material to be finished, the function of the finish, and the intended use of the project, and use appropriate methods to apply these finishes correctly (e.g., brush, spray, roller)	
	C3.3	Use appropriate tools, equipment, and techniques correctly and safely to install trim and hardware (e.g., baseboards, moulding, hinges, pulls)	
E: PROFESSIONAL PRACTICE AND CAREER OPPORTUNITIES			
E1	Identify and follow health and safety regulations, standards, and procedures related to the construction industry		
	E1.1	Identify laws, regulations, standards, regulatory agencies, and advocacy bodies related to health and safety in the construction industry (e.g., Workplace Safety and Insurance Board [WSIB], Ministry of Labour, Construction Safety Association of Ontario)	All projects are subject to assessment by the building care staff, Facilities Department, and Occupational Health and Safety Department. Students are advised on the outcome and comments of these agencies and shown how this advice promotes the safety of the group members and others.
	E1.2	Identify hazards related to materials, processes, and equipment used in construction (e.g., flammable solvents, toxic chemicals, sharp blades, moving parts in machinery), as well as resources and methods for reducing these hazards (e.g., Workplace Hazardous Materials Information System [WHMIS], safe handling and operating practices, personal protective equipment)	
	E1.3	Demonstrate an understanding of and adhere to safety practices and procedures for facilities, processes, materials, tools, and equipment used in construction (e.g., use of tool and equipment guards)	
	E1.5	Use protective clothing, gear, and equipment appropriately (e.g., dust mask, safety glasses)	Protective gear is kept on site and students are required to use them and understand the rational for their use.

Computer Technology TEJ2O			
A: COMPUTER TECHNOLOGY FUNDAMENTALS			
A1	Identify and describe the functions of, as well as important advances related to, electronic and computer components		
	A1.1	Identify basic electronic components and describe their functions (e.g., resistors limit current; capacitors store charge, pass high frequencies, and block DC; diodes restrict current in one direction; LEDs indicate current flow; transistors act as amplifiers or switches)	Students must design and modify sensor, control panel, and other digital and analogue circuitry to meet the needs of each new mission activity.
	A1.2	Use precise terminology to identify various types and features of computer hardware and interfaces (e.g., name, capacity, speed, bandwidth, connector types)	Students must reconstruct working computers from spare parts from non-functioning devices.
	A1.3	Identify the basic components and peripheral devices of a computer system (e.g., mainboard, CPU, power supply, hard drive, monitor, mouse, sound card, printer, scanner), and describe their functions	Students construct working computers from spare parts. Senior members instruct new members the function of each component.
	A1.4	Describe important advances in electronic components (e.g., development of semiconductor technology) and computer components (e.g., clock rates, fabrication techniques, bus types)	The wide range of computer equipment in use means that students must frequently evaluate the performance capabilities of the various equipment on hand with regards to the needs of the system.
A2	Demonstrate a basic understanding of computer networks and their components		
	A2.1	Compare various types of networks (e.g., local area network [LAN] versus wide area network [WAN], peer-to-peer versus client-server)	Students must maintain and modify the spacesim LAN (computers, video/audio, switches, hubs, etc.) as needed.
	A2.2	Describe the basic components of a network (e.g., workstations, server, network interface cards, routers, switches, hubs)	
	A2.3	Compare the various types of data transmission media for networks (e.g., fibre-optic cable, copper cable, wireless)	Task forces use CAT5e cable for all network and auxiliary communications to conform to OCDSB requirements.
	A2.4	Describe how individual workstations are identified on a network (e.g., logical and physical addressing, verification utilities)	The OCESS LAN consists of 10 to 20 computers and several switches and hubs as well as member-made peripheral devices. Old computers fail frequently and the active network configuration changes during the course of the mission activity, all students must be familiar with how network identifications work so as to troubleshoot connection issues during the mission.
A3	Demonstrate a basic understanding of binary numbers and digital logic		
	A3.1	Describe binary numbers, and convert positive integers between binary and decimal number systems (e.g., convert 247(10) to binary, convert 11110111(2) to decimal)	Students use the OCESS Circuit Interface Primer to learn how binary representation of numbers is used to integrate control panels, door sensor signals, and mock circuitry into the orbit software.
	A3.2	Describe how computers represent and process data using the binary number system (e.g., binary counting, binary codes, ASCII code)	
	A3.3	Derive the truth tables of the fundamental logic gates (e.g., AND, OR, NOT, NOR, NAND, XOR)	Maintenance and upgrades to sensor and control panel circuitry requires a thorough understanding of digital logic.
	A3.4	Write Boolean equations for the fundamental logic gates (e.g., AND output is $Y = A \bullet B$; OR is $Y = A + B$)	
B: COMPUTER TECHNOLOGY SKILLS			
B1	Install and configure the hardware and operating system of a workstation, and use file-management techniques effectively		
	B1.1	Connect and configure the hardware for a personal computer system, and install an operating system	Rebuilt computers must have new operating systems installed (Windows and Linux). The server computer have a network drive designator for each other computer on the LAN and maintains a orbit software image for each for easy upgrades and backups.
	B1.2	Describe the hardware requirements of operating systems (e.g., processor speed and bus width, available storage space, memory size and speed)	
	B1.3	Use file-management techniques to organize and back up files efficiently (e.g., move and rename files, store files on a network drive, use file-management and backup software)	

<table>
<tr><td colspan="4">TEJ2O</td></tr>
<tr><td rowspan="6">B2</td><td colspan="3">Construct and test simple interfaces and other electronic circuits</td></tr>
<tr><td>B2.1</td><td>Safely construct and test electronic circuits (e.g., LED circuit, flasher, timer), using both breadboard and soldering techniques to connect discrete components and/or integrated circuits</td><td rowspan="5">Door sensors, control panels, the planetary surface exploration robot, and mock circuitry are frequently reconfigured or rebuilt. Students must learn to design and build circuit interface cards and wiring - including wire runs through out the spacecraft.

As components fail, students must learn to troubleshoot the system to identify the point of failure. This requires the use of the network tester, multimeters, and the construction of test circuits and simple testing software,</td></tr>
<tr><td>B2.2</td><td>Use appropriate procedures to prevent damage to computer hardware and electronic components (e.g., anti-static straps and grounding mats for sensitive components; heat sinks for soldering solid-state devices)</td></tr>
<tr><td>B2.3</td><td>Describe and build an interface to connect a computer to a simple peripheral or robotic device (e.g., LED traffic light, DC motor, robotic arm)</td></tr>
<tr><td>B2.4</td><td>Trace the operation of a system consisting of a computer, program, interface, and external hardware to ensure that the interface circuit functions properly</td></tr>
<tr><td>B2.5</td><td>Use appropriate test equipment to measure electrical quantities (e.g., voltage, resistance)</td></tr>
<tr><td rowspan="4">B3</td><td colspan="3">Assemble and configure a simple computer network</td></tr>
<tr><td>B3.1</td><td>Install and configure a peer-to-peer (P2P) network, using appropriate software and connection devices</td><td rowspan="2">The OCESS LAN must be continually upgraded and maintained. As new computers are swapped out, each OS must be configured for the proper file sharing services to function.</td></tr>
<tr><td>B3.2</td><td>Enable network services (e.g., file sharing, print services)</td></tr>
<tr><td>B3.3</td><td>Install and use a network-enabled application or file-sharing scheme (e.g., game, database, peer-to-peer file sharing)</td><td>The orbit software system consists of more than 10 different applications and a large number of data files which must be passed between computers for the overall simulation system to function properly.</td></tr>
<tr><td rowspan="5">B4</td><td colspan="2">Install and use a variety of software</td><td></td></tr>
<tr><td>B4.1</td><td>Describe the differences between operating systems and applications software</td><td>Students are given preliminary instruction prior to being given computer management tasks.</td></tr>
<tr><td>B4.2</td><td>Install and configure software on a workstation (e.g., word-processing suite, driver for new hardware)</td><td>Orbit software must be reinstalled as upgrades are made and new computers are added.
Other software, such as Mumble VoIP, also must be installed and configured.</td></tr>
<tr><td>B4.3</td><td>Use software support systems to find technical information independently (e.g., help menu, online help, manuals)</td><td>Students use the OCESS wiki as well as online technical support websites for packages such as Mumble.</td></tr>
<tr><td>B4.4</td><td>Use utility software to perform basic maintenance functions (e.g., defragment a disk drive, undelete a file, determine available space on a storage device, restore a file from a backup)</td><td>The OS and hard drive on each computer must given yearly maintenance as frequent upgrades and multiple users create a cluttered file system over time.</td></tr>
<tr><td rowspan="5">B5</td><td colspan="3">Apply fundamental programming concepts to develop a variety of simple programs, including a program to control an external device</td></tr>
<tr><td>B5.1</td><td>Use a procedural programming language to define constants and variables, write expressions and assignment statements, and specify the order in which the operations are performed in a program</td><td rowspan="4">Students are in the process of writing new versions of all of the orbit software as part of a multi-year process. Each application is assigned to a single student.

Students use a version control system to co-ordinate the process of software development so that each components fits in to the overall system.

At the same time, students must be able to upgrade existing software as well as write testing software for troubleshooting the physical circuitry.

Software to control the land robot and submarine robot also must be completed and tested.</td></tr>
<tr><td>B5.2</td><td>Use input and output statements in a program (e.g., input a name and display it onscreen)</td></tr>
<tr><td>B5.3</td><td>Use a decision structure and a repetition structure in a program (e.g., determine if a user is old enough to drive, run a high-low guessing game, count from a starting value to an end value)</td></tr>
<tr><td>B5.4</td><td>Use a design process to plan, write, and test a computer program to control a simple robot or peripheral device (e.g., servo motor, LED display)</td></tr>
</table>

TEJ2O			
C: TECHNOLOGY,THE ENVIRONMENT, AND SOCIETY			
C1	Identify harmful effects of the widespread use of computers and associated technologies on the environment, as well as agencies that reduce these effects		
	C1.1	Identify harmful environmental effects of computer use (resources used and wastes created during production & disposal)	OCESS and Lisgar Collegiate are co-operating to set up an electronic waste recycling project along with a local recycler.
	C1.2	identify agencies providing resources and guidance for environmentally sound use and recycling of computers	

D: PROFESSIONAL PRACTICE AND CAREER OPPORTUNITIES			
D1	Follow appropriate health and safety procedures when assembling, using, and maintaining computer systems		
	D1.1	Use appropriate equipment, procedures, and techniques (e.g., use a wrist support, ensure power is off before opening the case of a computer, use proper lifting techniques when moving heavy equipment) to protect health and ensure safety when working with computers (e.g., to avoid musculoskeletal injuries, eye strain, repetitive strain injuries)	Safety procedures as dictated by the OCDSB are discussed when jobs are performed and are followed by each task force.
	D1.2	Identify issues related to Internet safety and personal identity security (e.g., protection of information stored on computers or transmitted over a network, identity theft, cyberstalking, cyberbullying, privacy policies)	Senior student members and the teacher advisor monitor the internet-based communication systems (email, facebook) to ensure that appropriate standards or behaviour are maintained. Communication from outside the membership is controlled and monitored so reduce the risk of inappropriate contact between students and individuals outside of the group.

Computer Engineering Technology TEJ3M			
A: COMPUTER TECHNOLOGY FUNDAMENTALS			
A1	Describe how computer components function, and discuss trends in the development of computer hardware		
	A1.1	Describe how the internal components of a computer function (e.g., CPU, mainboard, disk drives, RAM, chipset, video card, sound card, expansion slot)	See TEJ2O A1.3
	A1.2	Describe various standards for connecting computer components (e.g., parallel port, RS-232, USB, IEEE 1394, VGA, DVI)	Different interfaces are used for different purposes (LPTn for student made interface cards, USB for peripherals and Arduino microcontrollers, ethernet for the LAN)
A2	Describe the functions of BIOS and operating systems, and how they interact with each other and with computer hardware		
	A2.1	Describe the essential functions and other features of various operating systems (e.g., functions: management of resources, files, processes, and applications; features: services, usability, performance, applications such as text editor, web browser, or media player)	These expectations are covered in the process of troubleshooting and reconstructing computers from spare parts and installing a new OS.
	A2.2	Describe changes that may be required when upgrading hardware components or features of a computer system (e.g., BIOS updates, installation of drivers for new hardware, resolution of compatibility issues)	
	A2.3	Describe the essential functions performed by the BIOS firmware in computer systems (e.g., POST [power on self test], boot sequence, hardware recognition, detection of master boot record)	
	A2.4	Describe how the BIOS, hardware, and operating system of a computer interact	
A3	Describe the function of electronic components and the use of these components in control systems and other circuits, and calculate values for circuit components		
	A3.1	Identify and describe the functions of electronic components (e.g., resistor, capacitor, diode, LED)	See TEJ2O A1.1
	A3.2	Describe the function of electrical devices used in control systems (e.g., stepper motor, direct-current motor, touch sensor, accelerometer, optical sensor, power supply)	Robotic planetary surface exploration devices are designed and built.
	A3.3	Calculate the values of components in electronic circuits using fundamental laws (e.g., Ohm's law, Kirchhoff's laws)	Testing of circuits for door sensors, auxiliary communications, and mock devices.
	A3.5	Compare the advantages and disadvantages of interfacing using desktop computers, micro-controllers, and programmable logic controllers	Robotic planetary surface exploration devices are designed and built.
A4	Describe network concepts, services, and security		
	A4.1	Explain fundamental network concepts (e.g., bandwidth, throughput, full duplex, half duplex)	OCESS LAN upgrades and troubleshooting.
	A4.2	Explain the fundamental aspects of TCP/IP addressing as it pertains to workstations on a network (e.g., workstation IP address, subnet mask, MAC [media access control] address, default gateway address)	
	A4.3	Describe various services offered by servers to network clients (e.g., HTTP, FTP, SMTP, telnet, printing, file transfers and storage, login)	
A5	Demonstrate an understanding of the use of binary numbers, hexadecimal numbers, and Boolean algebra in computer logic and data processing		
	A5.1	Describe binary and hexadecimal numbers, and convert positive integers among decimal, binary, and hexadecimal number systems	Students use the OCESS Circuit Interface Primer to learn how binary representation of numbers is used to integrate control panels, door sensor signals, and mock circuitry into the orbit software. Maintenance and upgrades to sensor and control panel circuitry requires a thorough understanding of digital logic.
	A5.2	Compare binary and hexadecimal representation of addresses and data (e.g., absolute addressing, character codes, colours)	
	A5.3	Relate Boolean algebra to the fundamental logic gates and to combinations of these gates, using symbolic, algebraic, and numeric representations	

TEJ3M			
B: COMPUTER TECHNOLOGY SKILLS			
B1	Build, configure, and maintain a computer system, and connect peripheral devices		
	B1.1	Build a computer from parts to meet specified requirements (e.g., for gaming, business, entertainment, media centre, or graphic design)	These expectations are covered in the process of troubleshooting and reconstructing computers from spare parts and installing a new OS.
	B1.2	Use correct procedures to prevent damage to sensitive components (e.g., use anti-static straps and mats, disconnect power when inserting expansion cards)	
	B1.3	Install and configure peripheral devices in a computer system (e.g., printer, camera, external drives)	
	B1.4	Document maintenance and troubleshooting of computer hardware on a day-to-day basis (e.g., use a journal or log to record work done, time taken, problems found, solutions attempted, and results)	
B2	Set up, optimize, and back up a computer system		
	B2.1	Set up and configure a home office system (e.g., computer, scanner, printer, appropriate software)	These expectations are covered in the process of troubleshooting and reconstructing computers from spare parts and installing a new OS. System maintenance and network backup procedures are completed each semester.
	B2.2	Use system utilities for optimization and backup (e.g., defragment files; scan hard drives for defective sectors; run complete, incremental, and differential backups)	
	B2.3	Configure a computer system to use multiple operating systems (e.g., dual boot, virtual machines)	Students install Linux and Windows on computers.
B3	Design, construct, create diagrams for, and troubleshoot electronic circuits and interfaces for control systems		
	B3.1	Use a design process to design, safely construct, and test interfacing or robotics circuits (e.g., for LED traffic lights or motor control), using appropriate materials and techniques, including soldering	Door sensors, control panels, the planetary surface exploration robot, and mock circuitry are frequently reconfigured or rebuilt. Students must learn to design and build circuit interface cards and wiring - including wire runs through out the spacecraft. As components fail, students must learn to troubleshoot the system to identify the point of failure. This requires the use of the network tester, multimeters, and the construction of test circuits and simple testing software,
	B3.2	Troubleshoot an electronic circuit using appropriate methods and test equipment (e.g., isolation and substitution of components; multimeter, logic probe)	
	B3.3	Draw and interpret diagrams that represent circuit components and functions (e.g., schematic diagram, block diagram, flow chart)	
B4	Design, install, configure, test, and troubleshoot networks		
	B4.1	Design, install, and configure a peer-to-peer network (e.g., choose appropriate computers and network interfaces, construct cables, enable file sharing) using appropriate tools, materials, and equipment (e.g., UTP cable, 8P8C connectors, crimping tool, cable tester)	OCESS LAN upgrades and troubleshooting.
	B4.2	Draw diagrams of various LAN types (e.g., peer-to-peer, client-server) and topologies(e.g., bus, star, ring)	
	B4.3	Construct various network cables (e.g., straight-through, crossover)	Students make straight-through and crossover cables as needed.
	B4.4	Use a variety of methods to verify the operation of a network (e.g., visual inspection, ping, ipconfig, telnet, tracert, arp)	OCESS LAN troubleshooting takes place using physical examination, cable testers, pinging, and
	B4.5	Use a problem-solving process to troubleshoot networks	
B5	Demonstrate an understanding of fundamental programming concepts, and develop a program that interacts with an external device		
	B5.1	Use constants, variables, expressions, and assignment statements correctly, taking into account the order in which operations are performed	Students upgrade existing Orbit software as well as write test software for troubleshooting the physical circuitry. Software to control the land robot and submarine robot also must be completed and tested.
	B5.2	Use input statements, output statements, selection structures, and repetition structures in a program	

A task force also exists for developing an entirely new orbit software system

	B5.3	Use a design process to write, test, and debug a computer program that controls and/or responds to the inputs from an external device (e.g., LED array, motor, relay, infrared sensor, temperature sensor)	
TEJ3M			
C: TECHNOLOGY, THE ENVIRONMENT, AND SOCIETY			
C1	Describe environmental issues related to the widespread use of computers and associated technologies		
	C1.2	Outline how community partners and government agencies apply the reduce/reuse/recycle concept to computer technology	OCESS and Lisgar Collegiate are co-operating to set up an electronic waste recycling project along with a local recycler.

Computer Engineering Technology TEJ4M			
A. COMPUTER TECHNOLOGY FUNDAMENTALS			
A1	Demonstrate an understanding of internal buses and storage devices, and of advances in computer technology		
	A1.1	Describe the function of internal buses within computer systems (e.g., data bus; memory bus; address bus; buses in CPUs, RAM, and chipsets)	These expectations are covered in the process of troubleshooting and reconstructing computers from spare parts and installing a new OS.
	A1.2	Identify appropriate storage devices for various computing requirements (e.g., optical drives, flash drives, single and arrayed hard drives)	
A2	Demonstrate an understanding of system optimization and of permissions, attributes, firmware, and communication standards used in computer systems		
	A2.1	Describe how to assign permissions and attributes to drives, folders, and files with various operating systems (e.g., user permissions, archiving, encryption, compression)	User permissions must be set to allow data to be accessed and written by the server software and server independent parts of the simulation system.
	A2.2	Describe methods for optimizing a computer system (e.g., updating firmware, updating drivers, defragmenting files, allocating virtual memory)	These expectations are covered in the process of troubleshooting and reconstructing computers from spare parts and installing a new OS.
	A2.3	Describe the functions of the BIOS and other firmware in computer systems (e.g., boot process, hardware recognition, resource allocation, port settings, energy management)	
A3	Demonstrate an understanding of devices and electronic circuits in interfaces and control systems		
	A3.1	Use technical terminology to accurately describe the specifications for electronic components and computer interfaces	See TEJ4M sections A2.2 and B5
	A3.2	Describe the function and operation of various input devices, output devices, and electronic circuits used in interface and control systems(e.g., input devices: temperature sensor, light sensor, position encoder; output devices: AC motor, stepper motor; circuits: power supply, motor driver)	Arduino microcontroller-based sensors will be used for the robotic systems and where sensors for the simulator software are needed.
	A3.3	Calculate the values and operating parameters of electronic components in a circuit, using fundamental laws and circuit-analysis techniques(e.g., Ohm's law, Kirchhoff's laws)	See TEJ4M section B5
	A3.4	Draw and interpret diagrams that use standard symbols to represent electronic components and the operation of control systems (e.g., schematic diagram, block diagram, flow chart)	
	A3.5	Research and select components based on circuit requirements (e.g., use Internet searches, manufacturer's data sheets, supplier catalogues, and/or parts database)	
A5	Demonstrate an understanding of computer logic circuits and the representation, manipulation, and transmission of data by computers		
	A5.1	Perform arithmetic operations on positive and negative binary numbers (e.g., addition, subtraction) using two's complement representation	Door sensors, control panels, the planetary surface exploration robot, and mock circuitry are frequently reconfigured or rebuilt. Students must learn to design and build circuit interface cards. Students learn to troubleshoot the system to identify the point of failure using multimeters, test circuits and software. Students use the OCESS Circuit Interface Primer to learn how binary representation of numbers is used to integrate control panels, door sensor signals, and mock circuitry into the orbit software. Maintenance and upgrades to sensor and control panel circuitry requires a thorough understanding of digital logic.
	A5.2	Use Boolean logic (e.g., Karnaugh maps) to design a solution to a logic problem that has multiple inputs and outputs (e.g., manufacturing process, starting a car)	
	A5.3	Use Boolean logic and the laws of Boolean algebra to design, simplify, and build computer logic circuits using logic gates (e.g., adder circuit, decoder circuit)	
	A5.4	Describe the role of flip-flop circuits in the storage and flow of data (e.g., asynchronous counter, synchronous counter, shift register, memory register)	
	A5.5	Describe how computers store and work with different types of data, including numbers, characters, and arrays	

<table>
<tr><td colspan="4">TEJ4M</td></tr>
<tr><td colspan="4">B: COMPUTER TECHNOLOGY SKILLS</td></tr>
<tr><td rowspan="4">B1</td><td colspan="3">Build computer systems and connection media to meet specific requirements, using appropriate procedures, tools, and equipment</td></tr>
<tr><td>B1.1</td><td>Select appropriate components and build computer systems that meet specific requirements (e.g., gaming system, engineering workstation, media centre, control system, home office system)</td><td rowspan="3">See TEJ3M section B1</td></tr>
<tr><td>B1.2</td><td>Select and use appropriate procedures, tools, and diagnostic equipment when assembling computing devices (e.g., procedures: use of anti-static wrist strap and/or mat; tools: crimper; diagnostic equipment: multimeter, cable tester, oscilloscope)</td></tr>
<tr><td>B1.3</td><td>Construct and test connection media for interfacing a computer with an external device (e.g., serial cable, parallel cable)</td></tr>
<tr><td rowspan="3">B2</td><td colspan="3">Maintain and troubleshoot a variety of computer hardware and software</td></tr>
<tr><td>B2.1</td><td>Use a variety of sources to collect information for solving computer problems (e.g., Internet searches, technical reference materials)</td><td rowspan="2">OCESS uses second-hand computers and in-house software. As such, computer, network, and software troubleshooting is an ongoing concern.</td></tr>
<tr><td>B2.3</td><td>Use a logical approach to diagnose and troubleshoot computer hardware and software problems</td></tr>
<tr><td rowspan="5">B3</td><td colspan="3">Design, build, test, and troubleshoot interfaces and other circuits that meet specific design requirements</td></tr>
<tr><td>B3.1</td><td>Use a design process and appropriate software (e.g., circuit simulation software, CAD software) to design circuits</td><td rowspan="4">see TEJ3M section B3</td></tr>
<tr><td>B3.2</td><td>Construct circuits made from both discrete components and integrated circuits to perform specific functions (e.g., regulated power supply, electronic dice, audio amplifier, microcontroller-based alarm circuit)</td></tr>
<tr><td>B3.3</td><td>Safely construct electronic circuits for interfacing or robotic applications using appropriate materials, tools, and techniques, including soldering (e.g., materials: breadboard, printed circuit board, etchant, solder; tools: soldering iron, etch bath, third hand with magnifier)</td></tr>
<tr><td>B3.4</td><td>Test and troubleshoot electronic circuits, using appropriate methods (e.g., isolating and substituting components) and test equipment (e.g., multimeter, oscilloscope, logic probe), and modify the circuits to meet design requirements if necessary</td></tr>
<tr><td rowspan="3">B4</td><td colspan="3">Design, build, configure, maintain, and troubleshoot networks, and set up various network services for users</td></tr>
<tr><td>B4.1</td><td>Design and build a network (e.g., connection media, interconnection devices, peripherals, server, workstations) that meets user requirements</td><td rowspan="2">All network wiring and connections are done in-house. Networks are modified each year.
Troubleshooting network issues is an ongoing concern, especially during mission activities. As such, all students must be familiar with the processes required to do this.</td></tr>
<tr><td>B4.5</td><td>Apply logical troubleshooting techniques, using data from simulation and/or diagnostic tools (e.g., simulation software, packet sniffers, cable tester)</td></tr>
<tr><td rowspan="4">B5</td><td colspan="3">Demonstrate an understanding of programming concepts, and create programs that interact with external devices</td></tr>
<tr><td>B5.2</td><td>Apply programming concepts including subroutines, parameter passing, decision and repetition structures, arrays, and character representation</td><td rowspan="3">The OCESS computer simulation system incorporates external door sensors, control panels, mock circuitry, robotic devices, and low-voltage electrical control systems. All of these integrate with the software simulation environment. Students design, build, and troubleshoot hardware interface systems to accomplish this integration.</td></tr>
<tr><td>B5.3</td><td>Use a design process to create a program that interacts with a real-world device (e.g., traffic light, alarm system, robot, joystick)</td></tr>
<tr><td>B5.4</td><td>Write a low-level program that runs on a real or simulated controller device (e.g., programmable logic controller [PLC], microcontroller, assembler simulator)</td></tr>
</table>

Introduction to Computer Studies ICS2O			
A: Understanding Computers			
A1	Describe the functions of different types of hardware components, and assess the hardware needs of users		
	A1.1	Use correct terminology to describe computer hardware (e.g., USB, FSB, IEEE 1394 interface), speed measurements (e.g., megahertz), and size measurements (e.g., megabytes, gigabytes)	see TEJ2O A1.3 and TEJ3M A1.2
	A1.2	Describe the functions of the internal components of a computer (e.g., CPU, RAM, ROM, cache, hard drive, motherboard, power supply, video card, sound card)	
	A1.3	Describe the functions of common computer peripheral devices (e.g., printer, monitor, scanner, keyboard, mouse, speakers, USB flash drive)	
A3	Use the basic functions of an operating system correctly		
	A3.1	describe operating system functions that meet various user needs (e.g., running applications, organizing files, managing users, configuring peripherals)	Students set up OS on rebuilt computers and configure to meet needs of the simulation. They must describe this knowledge to the senior student training them.
	A3.2	use file management techniques to organize and manage files (e.g., copy, move, delete, rename; create shortcut)	Students are taught these skills and demonstrate them during the process of updating the spacesim file system and setting up macros to carry out automatic network updating.
	A3.3	Use general keyboard shortcuts to perform common tasks (e.g., cut, copy, paste, print, print window, print screen)	
A4	Demonstrate an understanding of home computer networking concepts		
	A4.1	Identify various networking applications and protocols (e.g., VoIP, streaming media, FTP, email, instant messaging)	Students set up and run a VoIP client/server application for mission communications (includes IM).
	A4.2	Describe the features and functions of wired and wireless networking hardware (e.g., NICs, routers, hubs, cables, modems)	Students must configure NICs into rebuilt computers. The OCESS network uses a switch and several hubs to for connectivity. CAT5 wires must be checked and re-run frequently as the needs of the system change.
	A4.3	Demonstrate an understanding of various methods for sharing network resources (e.g., shared file access, shared printer access, Internet access)	Students must demonstrate competence on the shared file access in use for sharing data within the simulation process. The new software package is being written by students to use a client/server data management system.
A5	Explain the importance of software updates and system maintenance to manage the performance and increase the security of a computer		
		A5.3 explain the importance of preventive maintenance (e.g., defragmenting a hard drive, deleting unused software and data files) to manage computer performance	Software applications and database files are upgraded frequently. Since the computers are in use when ever they are running, students must manually run system maintenance functions when needed.

<table>
<tr><td colspan="4">ICS2O</td></tr>
<tr><td colspan="4">B. Introduction to Programming</td></tr>
<tr><td rowspan="7">B1</td><td colspan="3">Describe fundamental programming concepts and constructs</td></tr>
<tr><td>B1.1</td><td>Use correct terminology to describe programming concepts</td><td rowspan="3">Students work in teams and so effective communication between team members is critical for success.</td></tr>
<tr><td>B1.2</td><td>Describe the types of data that computers can process and store (e.g., numbers, text)</td></tr>
<tr><td>B1.3</td><td>Explain the difference between constants and variables used in programming</td></tr>
<tr><td>B1.4</td><td>Determine the expressions and instructions to use in a programming statement, taking into account the order of operations (e.g., precedence of arithmetic operators, assignment operators, and relational operators)</td><td rowspan="9">The OCESS orbit software package consists of 10 major applications totalling approximately 15000 lines of code and many smaller applications to initialize and manage data files.

The software simulates a variety of systems such as: 1) the motion of objects within the solar system (moon, planets, asteroids, etc,); 2) changes to the motion of the spacecraft as a result of their orientations and engine thrust settings; 3) the atmosphere within the spacecraft compartments and the outside environment; 4) atmospheric gas supplies and fuel supplies; 5) radiation levels inside and outside of the spacecraft, 6) engineering and electrical systems in the spacecraft.

The current package consists of 10 major applications and has a total of approximately 15,000 code statements. A multi-year project to develop a new system is underway. It will ultimately involve at least twice as many lines of code. Both systems are or will be subject to continuous troubleshooting and upgrading as the needs of the simulation change and errors in the code are uncovered when new situations are encountered.</td></tr>
<tr><td>B1.5</td><td>Identify situations in which decision and looping structures are required</td></tr>
<tr><td>B1.6</td><td>Describe the function of Boolean operators (e.g., AND, OR, NOT), comparison operators (i.e., equal to, not equal to, greater than, less than, greater than or equal to, less than or equal to), and arithmetic operators (e.g., addition, subtraction, multiplication, division, exponentiation, parentheses), and use them correctly in programming</td></tr>
<tr><td rowspan="6">B2</td><td colspan="2">Plan and write simple programs using fundamental programming concepts</td></tr>
<tr><td>B2.2</td><td>Use variables, expressions, and assignment statements to store and manipulate numbers and text in a program (e.g., in a quiz program, in a unit conversion program)</td></tr>
<tr><td>B2.3</td><td>Write keyboard input and screen output statements that conform to program specifications</td></tr>
<tr><td>B2.4</td><td>Write a program that includes a decision structure for two or more choices (e.g., guessing game, rock-paper-scissors game, multiple-choice quiz, trivia game)</td></tr>
<tr><td>B2.5</td><td>Write programs that use looping structures effectively (e.g., simple animation, simple board games, coin toss)</td></tr>
<tr><td>B2.6</td><td>Explain the difference between syntax, logic, and run-time errors</td></tr>
<tr><td rowspan="5">B3</td><td colspan="3">Apply basic code maintenance techniques when writing programs</td></tr>
<tr><td>B3.1</td><td>Write clear and maintainable code using proper programming standards (e.g., indentation; naming conventions for constants, variables, and expressions)</td><td rowspan="2">These practices are maintained and enforced by the senior members of the software development task force.</td></tr>
<tr><td>B3.2</td><td>Write clear and maintainable internal documentation to a specific set of standards (e.g., program header: author, revision date, program name, program description; table of variable names and descriptions)</td></tr>
<tr><td>B3.3</td><td>Use a tracing technique to understand program flow and to identify and correct logic and run-time errors in a computer program</td><td>Use of the IDE’s debugging tools is used during testing and trouble shooting of software components.</td></tr>
<tr><td>B3.4</td><td>Demonstrate the ability to validate a computer program using test cases</td><td>All code components must be tested using test-bed software systems and full-up testing within the integrated orbit software package.</td></tr>
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<table>
<tr><td colspan="4">ICS2O</td></tr>
<tr><td colspan="4">C: Computers and Society</td></tr>
<tr><td rowspan="4">C2</td><td colspan="3">Describe computer use policies that promote environmental stewardship and sustainability</td></tr>
<tr><td>C2.1</td><td>Describe the negative effects of computers and computer use on the environment and on human health</td><td rowspan="3">The principal and chief custodian are assisting the OCESS students with setting up a regular electronic waste drop-off program. Waste would be assessed for usability within the OCESS program and all non-usable waste would be picked up by a local recycler.</td></tr>
<tr><td>C2.2</td><td>Identify measures that help reduce the negative effects of computers on the environment (e.g., school policies) and on human health</td></tr>
<tr><td>C2.4</td><td>Describe, on the basis of research, how and where recycled electronic waste is processed, and identify local companies and institutions that offer such services</td></tr>
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<table>
<tr><td colspan="4">Introduction to Computer Science ICS3U</td></tr>
<tr><td colspan="4">A: Programming Concepts and Skills</td></tr>
<tr><td rowspan="7">A1</td><td colspan="3">Demonstrate the ability to use different data types, including one-dimensional arrays, in computer programs</td></tr>
<tr><td>A1.1</td><td>Use constants and variables, including integers, floating points, strings, and Boolean values, correctly in computer programs</td><td rowspan="2">Software modules handle a variety of data types for different calculations, user input, and for maximizing the efficiency of data transfer between computers on the LAN.</td></tr>
<tr><td>A1.2</td><td>Demonstrate an understanding of how a computer uses various systems (e.g., binary, hexadecimal, ASCII, Unicode) to internally represent data and store information</td></tr>
<tr><td>A1.3</td><td>Use assignment statements correctly with both arithmetic and string expressions in computer programs</td><td>All of the software components assign a set of physical constants on launch.</td></tr>
<tr><td>A1.4</td><td>Demonstrate the ability to use Boolean operators (e.g., AND, OR, NOT), comparison operators (i.e., equal to, not equal to, greater than, less than, greater than or equal to, less than or equal to), arithmetic operators (e.g., addition, subtraction, multiplication, division, exponentiation, parentheses), and order of operations correctly in computer programs</td><td>Boolean logic operators are used especially within the applications that manage the interface between the simulation software and the external circuitry within the spacecraft.</td></tr>
<tr><td>A1.5</td><td>Describe the structure of one-dimensional arrays and related concepts, including elements, indexes, and bounds</td><td rowspan="2">All of the software applications use multidimensional arrays to store data for planetary objects within the simulation (mass, velocity components, atmosphere, etc.)</td></tr>
<tr><td>A1.6</td><td>Write programs that declare, initialize, modify, and access one-dimensional arrays</td></tr>
<tr><td rowspan="4">A2</td><td colspan="3">Demonstrate the ability to use control structures and simple algorithms in computer programs</td></tr>
<tr><td>A2.1</td><td>Write programs that incorporate user input, processing, and screen output</td><td>All of the orbit software have graphical user interfaces that display the relevant parameters of the spacecraft in a manner that resembles a real spacecraft control system and provides for user input both from keyboard and student-made control panels via parallel or USB input.</td></tr>
<tr><td>A2.2</td><td>Use sequence, selection, and repetition control structures to create programming solutions</td><td rowspan="2">Nested structures are used in many places to accomplish tasks such as calculating distances from one object to all the others within a loop that does this for all objects. Selection control is used in circumstances such as leaving a control loop when identifying contact between two objects.</td></tr>
<tr><td>A2.3</td><td>Write algorithms with nested structures (e.g., to count elements in an array, calculate a total, find highest or lowest value, or perform a linear search)</td></tr>
<tr><td rowspan="3">A3</td><td colspan="3">Demonstrate the ability to use subprograms within computer programs</td></tr>
<tr><td>A3.1</td><td>Demonstrate the ability to use existing sub-programs (e.g., random number generator, substring, absolute value) within computer programs</td><td rowspan="2">functions and subprograms (such as calculation of angle between three points, azimuth direction to selected destinations, airflow rate between two compartments) are used extensively throughout the orbit software system.</td></tr>
<tr><td>A3.2</td><td>Write subprograms (e.g., functions, procedures) that use parameter passing and appropriate variable scope (e.g., local, global), to perform tasks within programs</td></tr>
<tr><td rowspan="6">A4</td><td colspan="3">Use proper code maintenance techniques and conventions when creating computer programs</td></tr>
<tr><td>A4.1</td><td>Demonstrate the ability to identify and correct syntax, logic, and run-time errors in computer programs</td><td rowspan="5">All of these expectations are met through the work of the software development task force. The complexity of the software necessitates that new code and modification to code require both careful adherence to good coding practices (so subsequent task force members can pick up where others have left off) and extensive debugging and troubleshooting.</td></tr>
<tr><td>A4.2</td><td>Use workplace and professional conventions (e.g., naming, indenting, commenting) correctly to write programs and internal documentation</td></tr>
<tr><td>A4.3</td><td>Demonstrate the ability to interpret error messages displayed by programming tools (e.g., compiler, debugging tool), at different times during the software development process (e.g., writing, compilation, testing)</td></tr>
<tr><td>A4.4</td><td>Use a tracing technique to understand program flow and to identify and correct logic and run-time errors in computer programs</td></tr>
<tr><td>A4.5</td><td>Demonstrate the ability to validate a program using a full range of test cases</td></tr>
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<table>
<tr><td colspan="4">ICS3U</td></tr>
<tr><td colspan="4">B: Software Development</td></tr>
<tr><td rowspan="3">B1</td><td colspan="3">Use a variety of problem-solving strategies to solve different types of problems independently and as part of a team</td></tr>
<tr><td>B1.1</td><td>Use various problem-solving strategies (e.g., stepwise refinement, divide and conquer, working backwards, examples, extreme cases, tables and charts, trial and error) when solving different types of problems</td><td rowspan="2">The work of the software development task force addresses each of these expectations.</td></tr>
<tr><td>B1.2</td><td>Demonstrate the ability to solve problems independently and as part of a team</td></tr>
<tr><td rowspan="6">B2</td><td colspan="3">Design software solutions to meet a variety of challenges</td></tr>
<tr><td>B2.1</td><td>Design programs from a program template or skeleton (e.g., teacher-supplied skeleton, Help facility code snippet)</td><td rowspan="4">The work of the software development task force addresses each of these expectations.

A given application can have more than one students working on it. Senior students can hand off tasks such as flow charts, pseudocode, skeleton code to other students to complete the development process.

Developers can use modules designed by other students to accomplish common tasks.</td></tr>
<tr><td>B2.2</td><td>Use appropriate vocabulary and mode of expression (i.e., written, oral, diagrammatic) to describe alternative program designs, and to explain the structure of a program</td></tr>
<tr><td>B2.3</td><td>Apply the principle of modularity to design reusable code (e.g., subprograms, classes) in computer programs</td></tr>
<tr><td>B2.4</td><td>Represent the structure and components of a program using industry-standard programming tools (e.g., structure chart, flow chart, UML [Unified Modeling Language], data flow diagram, pseudocode)</td></tr>
<tr><td>B2.5</td><td>Design user-friendly software interfaces (e.g., prompts, messages, screens, forms)</td><td>Each application requires a graphical interface to mimic a spacecraft control panel or mission control station.</td></tr>
<tr><td rowspan="4">B3</td><td colspan="3">Design algorithms according to specifications</td></tr>
<tr><td>B3.1</td><td>Design simple algorithms (e.g., add data to a sorted array, delete a datum from the middle of an array) according to specifications</td><td rowspan="3">Each of the orbit software components includes a number of subprogram modules that perform common tasks such as setting up the solar system database on launch of the software, calculation of angles and distances, and handling of exceptions (expected or unexpected) such as division by zero on spacecraft touchdown when calculating gravitational forces so that program execution continues even in the case of unexpected errors.</td></tr>
<tr><td>B3.2</td><td>Solve common problems (e.g., calculation of hypotenuse, determination of primes, calculation of area and circumference) by applying mathematical equations or formulas in an algorithm</td></tr>
<tr><td>B3.3</td><td>Design algorithms to detect, intercept, and handle exceptions (e.g., division by zero, roots of negatives)</td></tr>
<tr><td colspan="4">C: Computer Environments and Systems</td></tr>
<tr><td rowspan="6">C3</td><td colspan="3">Demonstrate an understanding of the software development process</td></tr>
<tr><td>C3.1</td><td>Demonstrate an understanding of an integrated software development environment and its main components (e.g., source code editor, compiler, debugger)</td><td rowspan="5">The work of the software development task force addresses each of these expectations. C++ and Freebasic IDEs are used to carry out the software development process. New task force members are instructed as to the different components of the development environment by senior students.</td></tr>
<tr><td>C3.2</td><td>Work independently, using support documentation (e.g., IDE Help, tutorials, websites, user manuals), to design and write functioning computer programs</td></tr>
<tr><td>C3.3</td><td>Explain the difference between source code and machine code</td></tr>
<tr><td>C3.4</td><td>Explain the difference between an interpreter and a compiler</td></tr>
<tr><td>C3.5</td><td>Explain the difference between the functions of applications, programming languages, and operating systems</td></tr>
</table>

Computer Science ICS4U			
A: Programming Concepts and Skills			
A1	Demonstrate the ability to use different data types and expressions when creating computer programs		
	A1.1	Demonstrate the ability to use integer division and resultant remainders in computer programs	Integer and other data types are converted back and forth to string and bitmaps in order to facilitate the more rapid transfer of data between computers within the simulation system.
	A1.2	Demonstrate an understanding of type conversion (e.g., string-to-integer, character-to-integer, integer-to-character, floating point-to-integer, casting in an inheritance hierarchy)	
	A1.3	Demonstrate the ability to use non-numeric comparisons (e.g., strings, comparable interface) in computer programs	
	A1.4	Demonstrate an understanding of the limitations of finite data representations (e.g., integer bounds, precision of floating-point real numbers, rounding errors) when designing algorithms	This problem must be dealt with in many situations within the software. The scale of stored values, in some cases, through more than 20 orders of magnitude, especially with measurements of distance. Rounding errors have been a particular problem when dealing with multiple solar systems. Methods, such as non-fixed centres of reference, have had to be adopted to reduce the precision to magnitude ratio to practical levels.
	A1.5	Describe and use one-dimensional arrays of compound data types (e.g., objects, structures, records) in a computer program	Many multidimensional arrays and more complex data structures are used to manage the different classes of objects within the simulation.
A2	Describe and use modular programming concepts and principles in the creation of computer programs		
	A2.1	Create a modular program that is divided among multiple files (e.g., user-defined classes, libraries, modules)	The simulation process is distributed across more than 10 different computers communicating data over the LAN. This is the highest level of modularity within the simulation. Within individual applications, each process is written as a separate code module to made debugging easier and program flow managable.
	A2.3	Demonstrate the ability to modify existing modular program code to enhance the functionality of a program	
A3	Design and write algorithms and subprograms to solve a variety of problems		
	A3.1	Demonstrate the ability to read from, and write to, an external file (e.g., text file, binary file, database, XML file) from within a computer program	Data files are the primary method for passing data between applications within the simulation system.
	A3.2	Create linear and binary search algorithms to find data in an array	Data file management: rewriting of start-up files;
	A3.3	Create subprograms to insert and delete array elements	
	A3.5	Create algorithms to process elements in two-dimensional arrays (e.g., multiply each element by a constant, interchange elements, multiply matrices, process pixels in an image)	Planetary surface images must be processed as part of the analytical process. Students will be shown procedures for processes such as sharpening, edge enhancement to more complex processes such as image autocorrelation. They will have to write code to carry out these procedures.
A4	Use proper code maintenance techniques when creating computer programs		
	A4.1	Work independently, using support documentation (e.g., IDE Help, tutorials, websites, user manuals), to resolve syntax issues during software development	The programming task force uses all of these resources.
	A4.2	Develop and implement a formal testing plan (e.g., unit testing, integration testing, regression testing) for a software project to ensure program correctness	Testing from the level of program modules to system-wide event testing is carried out throughout the school year.
	A4.3	Create fully documented program code according to industry standards (e.g., doc comments, docstrings, block comments, line comments)	Documentation is maintained within the code, within an online document clearing/build management system, and within the OCESS wiki.
	A4.4	Create clear and maintainable external user documentation (e.g., Help files, training materials, user manuals)	

<table>
<tr><td colspan="4">Visual Arts   AVI2O</td></tr>
<tr><td colspan="4">A: CREATING AND PRESENTING</td></tr>
<tr><td rowspan="2">A2</td><td colspan="3">The Elements and Principles of Design: apply elements and principles of design to create art works for the purpose of self-expression and to communicate ideas, information, and/or messages</td></tr>
<tr><td>A2.2</td><td>Apply elements and principles of design as well as art-making conventions to create art works that communicate ideas, information, or messages, and/or that convey a point of view on an issue (e.g., use colour, line, shape, contrast, and emphasis when creating an art work that addresses an issue in their local community)</td><td>Planning of the planetary surface by simulator team, accounting for research results of expected surface features, mission goals, and discoverable phenomena.
Plan procedures to produce a safe, durable, and realistic-looking landscape diorama.</td></tr>
<tr><td colspan="4">Exploring and Creating in the Arts   AEA3O</td></tr>
<tr><td colspan="4">A: CREATING AND PRESENTING</td></tr>
<tr><td rowspan="2">A1</td><td colspan="3">The Creative Process: apply creative process to create integrated art works, individually and/or collaboratively</td></tr>
<tr><td>A1.1</td><td>Use a variety of strategies (e.g., brainstorming with a partner, think-pair-share, mind maps, graphic organizers) to generate innovative ideas and to develop and refine detailed plans to address an integrated art challenge, individually and/or collaboratively (e.g., the challenge to create a performance piece or installation on a theme related to nature)</td><td>Planning of the planetary surface by simulator team, accounting for research results of expected surface features, mission goals, and discoverable phenomena.
Plan procedures to produce a safe, durable, and realistic-looking landscape diorama.</td></tr>
<tr><td colspan="4">Visual Arts   AVI4M</td></tr>
<tr><td colspan="4">A: CREATING AND PRESENTING</td></tr>
<tr><td>A3</td><td colspan="3">Production and Presentation: produce art works, using a variety of media/materials and traditional and emerging technologies, tools, and techniques, and demonstrate an understanding of a variety of ways of presenting their works and the works of others.</td></tr>
<tr><td></td><td>A3.1</td><td>Use with increasing skill a wide variety of media, including alternative media, and current technologies to create two- and three dimensional art works for a variety of purposes (e.g., extend their skills in the manipulation of a variety of media and technologies to create a sculpture for an outdoor space)</td><td rowspan="2">Planning of the planetary surface by simulator team, accounting for research results of expected surface features, mission goals, and discoverable phenomena.
Plan procedures to produce a safe, durable, and realistic-looking landscape diorama.

Make use of industry techniques for landscape fabrication (such as chicken wire attached to framing elements which is then covered with aluminum foil and sheetrock compound)

Procedures to effect realistic and functional decorative elements must be devised and implemented.</td></tr>
<tr><td></td><td>A3.2</td><td>Use with increasing skill a wide variety of traditional and current materials, technologies, techniques, and tools to create original art works for a variety of purposes and audiences (e.g., select materials that are highly appropriate for an art work that is intended to convey a message to their peers)</td></tr>
<tr><td colspan="4">Visual Arts   AVI4E</td></tr>
<tr><td colspan="4">A: CREATING AND PRESENTING</td></tr>
<tr><td>A1</td><td colspan="3">The Creative Process: apply the creative process to create a variety of art works, individually and/or collaboratively</td></tr>
<tr><td></td><td>A1.1</td><td>Use a variety of strategies, individually and/or collaboratively, to generate, explore, and reflect on ideas and to develop and revise plans for the creation of art works, including applied and commercial art works (e.g., extend their skills in brainstorming and research to generate and explore a range of creative ideas; reflect on ideas and choose one that is suitable for the creative challenge; use strategies such as thumbnail sketches, diagrams, notes, and/or outlines to help them develop detailed plans; reflect on and revise their plans)</td><td rowspan="2">Planning of the planetary surface by simulator team, accounting for research results of expected surface features, mission goals, and discoverable phenomena.
Plan procedures to produce a safe, durable, and realistic-looking landscape diorama.

Make use of industry techniques for landscape fabrication (such as chicken wire attached to framing elements which is then covered with aluminum foil and sheetrock compound)

Procedures to effect realistic and functional decorative elements must be devised and implemented.</td></tr>
<tr><td></td><td>A1.2</td><td>Apply the appropriate stages of the creative process to create a variety of art works, including applied and commercial art works, in areas of personal interest (e.g., painting, sculpture; use checklists to ensure completion of the stages of the creative process that are most appropriate for the creative challenge)</td></tr>
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