M2019 Pre-planning questions

Part 1: Fuel used to recharge main atmosphere tanks

At what rate is O2 consumed by the crew?
What extra factor should we multiply this by to account for stress, exercise, etc.
How many times will this necessitate recharging the main O2 tanks?

How much O2 & N2 is used to repressurise the airlock
How many times will we need to do this?
How many times will this necessitate recharging the main O2 and N2 tanks?

How many times do we anticipate needing to repressurise other rooms in the hab?
How many times will this necessitate recharging the main O2 and N2 tanks?

Each time a tank is recharged, it uses up to 160 kg of HAB fuel (if we need to power up just for this).
Calculate the total fuel load needed to account for main tank recharging for the mission.

Part 2: Background fuel consumption rates for AYSE and HAB

Aside from solar events, will the RAD shields be needed...
  at any point during the mission while docked with AYSE?
  while on the surface of 16-Psyche in the Hab?

Given the answers to the previous questions,
What is a reasonable fuel consumption rate for AYSE with gravity on and engines off?
What is a reasonable fuel consumption rate for the Hab with gravity and engines off

Part 3: Emergency fuel for solar events

What fuel consumption rate do the rad shields generate at 100% (both) for AYSE?
at 30% (one) for the HAB?
How long does a typical solar event last?
How much contingency fuel should be carried for protection from solar events?

Part 4: Propulsion fuel use

Can the Hab safely descend to the surface of 16-Psyche with a full fuel load?
i.e., can it abort a reasonably fast descent without dumping fuel if an engine or other failure occurs?

Can the Hab remain on the surface for the duration of the scheduled surface time (about 70 hours) without needing to return to AYSE to refuel if it lands with a full fuel load?
i.e., needs enough fuel on board at the end of 70 hours to ascend and dock with AYSE with more than 45 minutes of reserve fuel.

How much propulsion fuel is AYSE going to require for the 3 legs of the mission: earth-ceres, ceres-16psyche, 16psyche-earth?

How can the last leg of the mission be altered to use less fuel if more is used than anticipated during the rest of the mission?

Daily Duty Shifts

Astronauts

Astronauts are at 440 Albert in the simulation area from 0800 Feb. 19 to 1500 Feb. 23.
Sleep shift cycles commence at 2000 and end at 1200 the next morning.

Mission Control (MC) Note: all MC activities on February 23 take place at 440 Albert.

MC Lisgar:	AM shift	0800-1200 (open MC, start computers, take over control)
	PM shift	1200-1600
	Evening shift	1600-2100 (close MC, shut down hardware, release control)
MC 440 Albert	Evening shift	2100-0001
	Night shift	0001-0800

Simulators (all shifts take place at 440 Albert St.)

AM shift	0800-1200
PM shift	1200-1600
Evening shifts	1600-2100
	2100-0001
Night shift	0001-0800

Adult Supervisors

440 Albert St. Supervisors sign up for shift blocks.

Each supervisor
- reviews previous shift with replacement
- turns over sign-in sheet, binder, cell phone to replacement
- consults with simulators about planned activities

Lisgar

Adult supervisor arrives at 1600
- advises custodian/440 supervisor of arrival
- consults with MC staff on current status and planned activities

At 2100: Open Albert St. MC, close down Lisgar MC.
- activities at Lisgar end for the night.
- supervisor advises custodian of departure
- supervisor verifies that all students are picked up and depart.

OCESS Mission 2019

Mission Objectives:

1) Asteroid Mining

The mission will seek to assess the suitability for using 16-Psyche as a source of extractable metals, especially Rare Earth metals. If metal resources are present at high enough concentrations, it could be more economical to mine resources for use in space off of 16-Psyche and send them on a lunar capture transfer orbit than it is to lift materials out of Earth's gravity well. It may also be less expensive to mine Rare Earth metals for transport to Earth as reserves of such materials on Earth become depleted.

Aside from the question of whether the desired metals are present in sufficient quantity, there are two other significant questions to answer. First, is the physical character of the planetary body such that sufficient quantities and in sizes that can be removed easily and safely? Second, has alteration by solar and cosmic radiation produced undesirable isotopes within the easily accessible portion of the body.

One of the astronauts and two of the mission control team will be made up of representatives of a consortium of mining companies. The consortium is providing 50% of the funding for the mission, including any excesses needed to deal with unforeseen events during the mission. It will be the responsibility of these individuals to work with the astronauts and mission control team to ensure that the goals of this part of the project are met if doing so does not impart a serious added risk to the mission.

The astronauts will carry out observations of the surface geology of the asteroid from orbit and from the landing site. They also will carry out seismic analyses to extend the surface knowledge into the deep subsurface.

Ocess and the consortium will evaluate the economic feasability of mining this asteroid as well as the potential economic benefits and costs of restricted and unrestricted mining activities on this asteroid.

2) Origins of the Asteroid

16-Psyche represents an uncommon, and perhaps unique variety of asteroid: a large body (over 100 km across) composed almost entirely of native metals. The mission will seek to evaluate 16-Psyche as potential remnant planetary core. If so, it would serve as a laboratory to test models of how the cores of rocky planets function. It also could serve as a means for testing how the asteroid belt formed. If 16-Psyche is the remnant core of a planetary body that broke up some time in the past, its composition and structure may hold clues as to how the outer and inner core of a rocky planet interact with the rocky mantle. It also might hold clues as to whether the asteroid belt is largely made up of material that never came together to form a planetary body or whether a significant proportion of the material in the belt is derived from a large rocky planet that formed then subsequently broke up.

As part of this assessment, a stop-over analysis of the core of Ceres will be carried out using seismic imaging.

An investigation of the presence of water, hydroxyl free radicals, and other volatile compounds will be carried out on 16-Psyche as well. An attempt will be made to identify the possible sources of these substances, if they are found.

Timeline: Mission 2019 16-Psyche

Day	Time	Mission Time 2019	Activity
Tuesday, February 19	0700-0900	50:07:00:00	Students arrive at 440 room W027 and Lisgar room 414, @ 440: stow personal gear, start up network, verify network synchronization, verify proper functioning of all software elements. Establish communications with MC @ Lisgar room 414. @ 414: start up network, verify network synchronization, verify proper functioning of all software elements. Check equipment & consumables lists with MC. Run through pre-launch checklists with MC. All astronauts enter the spacecraft and go to launch stations. MC and astronauts proceed through pre-launch checklist.
	0900-1200	50:09:00:00 50:10:13:35 50:10:14:25 50:10:36:46 50:10:59:05 50:11:51:51 50:11:53:20	MC and astronauts proceed through launch checklist. Final status checks Launch to orbit procedures. Dock with AYSE unit. Initiate transfer orbit to Ceres. - 9 g acceleration to 50 km/s and coast to 50000 km alt - EECOM/Engineering GO/NO-GO Assessment - 15 g acceleration to 75 km/s and coast to 500000 km alt - MECO - course correction burn 1 MC confirms correct course. Crew Lunch prep 1130 Simulator shift change.
	1200-1500	 58:09:40:00 59:12:21:00 59:13:03:12 59:13:59:30 59:14:56:00	Crew meal & clean-up Fuel consumption calculations. Preparations for Ceres seismic survey Go over course correction process Course correction burn 2 Fuel consumption calculations Final conference with MC on seismic sampling process Course correction burn 3 Retro burn MECO Periapsis @ 40 km Orbit Circularisation Orbit 1: mapping and geophone deployment 1500 Simulator shift change.

	1500-1800	59:17:39:00 59:19:19:00 59:19:22:30 59:20:16:00 59:20:18:00 61:10:49:00	Orbit 2: seismic impactor deployed; data collection Test remote sensing equipment Confirm data is complete and orbit 3 not needed Initiate transfer orbit to 16-Psyche - 5 g burn - 15 g burn - MECO Course correction burn 1 Fuel consumption calculations. MC confirms correct course. Transfer copy of seismic data to MC. Analyse seismic data with MC. Course correction burn 2
	1800-1900		Meal prep, supper, cleanup. Go over plans for arrival at 16-Psyche and initial experiments on orbit with mission control.
	1900-2100	63:08:53:36 63:09:00:00 63:09:56:00	Final course correction burn as needed to set periapsis to 2000 km 15 g retro burn starts. MECO at 2000 km ccw prograde Arrival Tasks: assess radiation, electrostatic, and other conditions launch probe to assess electrostatic risks establish max EVA time limits fuel consumption calculations assess fuel available vs expected future consumption assess spacecraft systems assess stability of AYSE's orbit - adjust as needed Stay/Abort Decision **2000 hrs Astro team 1 sleep shift starts.** Undocking checklist completed. Undocking & descent to 40 km 2100 hrs: close Lisgar MC & open 440 Albert MC com and network checks
	2100-0001	63:12:00:00 63:14:25:00 63:16:50:00 63:19:15:00	Orbit 1: mapping (radar topography, visual imaging) Orbit 2: remote sensing thermal, magnetic, gravity Orbit 3: Spectrospcopy Orbit 4: seismic investigation <u>Projects for the night</u> (Astronauts + MC) 1) Crater density (crater counts) comparisons to moon, ceres. 2) Is the surface of this asteroid old or young, geologically active or not? 3) Mapping elemental abundances to determine surface composition 4) What is the bulk composition of the asteroid? 5) Are there any internal structures, void spaces, caverns at surface? 6) What is the best landing site? - relationship between metallic and rocky components - ability to sample metallic components for trace rare earths

Wednesday, February 20	0001-0400		**0001 hrs Astro team 2 sleep shift starts.** MC + Astronauts: continue data gathering and analysis (questions 1-6) MC: analyse HAB fuel consumption rates for surface mission durability. Write initial report to mining consortium.
	0400-0800		**0004 hrs Astro team 3 sleep shift starts, team 1 sleep shift ends.** MC + Astronauts: continue data gathering and analysis (questions 1-6) MC w/ assistance from Astronauts develop and test landing procedure and checklist at max fuel load as well as lift-off and ascent procedures for a variety of fuel loads. Estimate minimum time needed for an emergency liftoff and re-docking with AYSE. MC evaluates AYSE orbit stability, likely location at planned departure, and mission abort ascent profile for current day.
	0800-0900		**0800 hrs Astro team 2 sleep shift ends.** Reopen Lisgar MC, close Albert St. MC On shift astronauts prep, eat breakfast, clean up. Breakfast is stored for remaining crew at end of sleep shift.
	0900-1000		Proposed landing site submitted to flight director & Science director. Flight director, science director, and mission commander make final selection for landing site. Landing procedures and checklist are reviewed with MC.
	0900-1000		Landing checklists are completed. Landing procedures are carried out.
	1000-1200		EVAs conducted: 1) Evaluate spacecraft status and landing site safety (mission commander with rescue person at airlock door). Evaluate surface radiation levels. 2&3) Initial mapping of landing site: a) overview + map b) distribution of material types c) location of major features d) assess presence of atmosphere
	1200-1300		**1200 hrs Astro team 3 sleep shift ends.** Astros: lunch prep, consumption, cleanup Astros: Assess state of spacecraft for safety. Report to MC. MC evaluates data from initial mapping EVAs.
	1300-1500		Review sites and materials/structures to sample with MC EVA 4) refine descriptions of significant surface features. EVA 5&6) sample collection Evaluate sites for detailed seismic survey and heat flow measurements consulting with MC.

	1500-1700		EVA 7) Set up seismic shock device and signal recorder lines. Activate seismic recorders and shock timer. Catalogue samples. Begin sample analysis in hotlab: - sample descriptions - compositional analysis
	1800-1900		Astros: supper prep, consumption, cleanup. MC: evaluate science progress against the overall plan. Astros: Write interim report to mining consortium.
	1900-2100		EVA 8) drill and insert heat-flow thermocouple probes and activate. Analyse seismic test data and relate to planet-wide seismic profile. EVA 9) measure and evaluate one of the significant surface features. Monitor seismic recorder signal to establish a background signal and frequency of impact events. **2000 hrs Astro team 1 sleep shift starts.** Use AYSE radar to map location and velocities of nearby micro asteroids. Evaluate threat level for impacts. 2100: close Lisgar MC & open 440 Albert MC com and network checks
	2100-0001		Evaluate need for and ability to conduct EVAs before 0800 day 3 Add unscheduled EVAs to daily plan. Analysis of seismic data. Down time for homework/recreation.
Thursday, February 21	0001-0800		**0001 hrs Astro team 2 sleep shift starts.** Samples are described, analysed, and logged. MC conducts research to assist astronaut analysis. MC and astronauts go over photos from EVAs to plan next EVAs - investigate relationship between metallic & rocky componenets - assay sampling - locations for drill core extraction identified - unforeseen aspects of the surface/subsurface **0400 hrs Astro team 3 sleep shift starts, team 1 sleep shift ends.** MC evaluates AYSE orbit stability, likely location at planned departure, and mission abort ascent profile for current day.
	0800-0900		0800: reopen Lisgar MC, close Albert St. MC com and network checks **0800 hrs Astro team 2 sleep shift ends.** On shift astronauts prep, eat breakfast, clean up. Astros: Assess state of spacecraft for safety. Report to MC. Drill core sites submitted to MC flight director & science director. Final list sited on photos & surface map and uploaded to astronauts.

	0900-1200		EVA 10 - 13) - drill coring device is set up & left to complete core extraction at each of the selected sites. - surface sampling while drill core is set up Sample analysis continues. Detailed assessment of state of the spacecraft - engineering systems - door seals and compartment integrity: pressure test. - consumable supplies, - esp. atmospheric gases - evaluate need for gas recharging - schedule **1200 hrs Astro team 3 sleep shift ends.**
	1200-1800		Astros: lunch prep, consumption, cleanup Unscheduled EVAs carried out. Sample analysis continues. MC/Astro research team to evaluate data to date to address: 1) possibility that 16-psyche is a planetary core fragment and, if so, what size planet would it have come from and how does this relate to the asteroid belt. 2) feasability of breaking off suitable sized blocks of asteroid material for transport to moon based on observed integrity from seismic imaging.
	1800-1900		Astros: supper prep, consumption, cleanup.. MC: - assess progress towards mission goals. - assess need for further data to address the two primary mission objectives
	1900-2100		Core logging and analysis. Analysis of other samples continues. Further EVAs as needed. **2000 hrs Astro team 1 sleep shift starts.** Assessment of fuel state. MC/Astronauts evaluate radiation accumulated doses. 2100: open 440 Albert MC and close down Lisgar MC com and network checks
	2100-0001		Samples are described, analysed, and logged. Down time for homework/recreation. **0001 hrs Astro team 2 sleep shift starts.**
Friday, February 22	0001-0800		Samples described, analysed, and logged. Down time for homework/recreation. MC & Astros evaluate need for additional planet-wide or local seismic exploration or spectroscopy to evaluate potential for mineral exploitation. **0400 hrs Astro team 3 sleep shift starts, team 1 sleep shift ends.** MC evaluates AYSE orbit for rendezvous abort profile for current day. MC evaluates fuel use and mission durability up to planned departure.

	0800-0900		0800: reopen Lisgar MC, close Albert St. MC com and network checks **0800 hrs Astro team 2 sleep shift ends.** On shift astronauts prep, eat breakfast, clean up. Astros: Assess state of spacecraft for safety. Report to MC. Recommendations for further EVAs, local collection needs, and planetary data collection are discussed and a plan for the day is designed.
	0900-1200		Morning plan is carried out. Detailed assessment of state of the spacecraft - engineering systems - door seals and compartment integrity: pressure test. - consumable supplies, - esp. atmospheric gases - evaluate need for gas recharging - schedule **1200 hrs Astro team 3 sleep shift ends.**
	1200-1800		Afternoon plan is carried out. Remote diagnostic checks run on AYSE systems.
	1800-1900		Astros: supper prep, consumption, clean-up
	1900-2100		Final assessment of science needs related to mission goals. Final science EVAs are carried out. Samples are packaged for transport to earth. 2100: open 440 Albert MC and close down Lisgar MC com and network checks Sleep shift cycle begins.
	2100-0001		MC simulates Earth return procedures and revises as needed. - fuel needed for planned transfer orbit is matched against remaining fuel and contingency needs. Details of transfer orbit are discussed with astronauts. **2000 hrs Astro team 1 sleep shift starts.** Samples are described, analysed, and logged. Down time for homework/recreation. Final Science EVA Engineering diagnostic checks and low thrust engine check EECOM diagnostic checks. **2330 hrs Astro team 2 sleep shift starts.**

Saturday, February 23	0001-0800		Samples are described, analysed, and logged. Down time for homework/recreation. **0300 hrs Astro team 3 sleep shift starts, team 1 sleep shift ends.** Detailed assessment of state of the spacecraft - engineering systems - door seals and compartment integrity: pressure test. - consumable supplies, - esp. atmospheric gases - evaluate need for gas recharging - schedule - all stores, equipment, personal effects are stored for flight **0630 hrs Astro team 2 sleep shift ends.** Pre-launch checklist is completed. Landing procedures are practiced by MC and refined. MC evaluates AYSE orbit stability, likely location at planned departure, and mission abort ascent profile for current day.
	0800-0900	66:13:00:00	Astros: Assess state of spacecraft for safety. Report to MC. Final EVA for flight readiness check. Final interior readiness for flight check. Liftoff checklist completed Liftoff and ascent to AYSE AYSE docking
	0900-1100	66:16:00:00	Transfer orbit is initiated: 15 g to 5.00×10^5 m/s. Course correction burn (1) **1000 hrs Astro team 3 sleep shift ends.** Astronauts prep, eat breakfast, clean up. Course correction burn (2) (50000000 km) Course correction burn (3) (1000000 km) Retro Burn: 15 g to 100 km ccw prog lunar orbit. Lunar Orbit circularization
	1100-1200		Transfer orbit to earth initiated: 15 g to 50000 m/s Course correction burn. 150000 km Retro burn: 5 g to 400 km ccw prog earth orbit. AYSE undocking Pre-landing checklist is carried out. De-orbit burn at 180.82^o phase angle to OCESS -100 m/s Landing at OCESS

	1200-1500		Initial debriefing is carried out. Personal effects are packed up. Samples are secured. Space craft, MC, and planetary surface are cleaned. Assignments for post-mission report are finalized. All hardware is shut down and all power sources are disconnected. Parents arrive to pick up students.
	1500		Room W027 is checked, locked, and custodian is advised of departure.

Mission 2019 Flight Plan

load m2019f
target = AYSE
centre = earth
ref = earth
load 4000 kg HAB fuel
AYSE fuel should be at 501000 - leave it there.
NAV = deprt ref

Advance time to 2019 50 10 00 00

Launch

at HRT phase angle = 12.5°	set engine thrust to 62% set NAV = MAN
at HRT phase angle = 11°	2019 50 10 14 25 ignite SRBs ("w" in mirror) increase thrust to 70% set target to Earth
at Qmax	increase thrust to 90%
at 15 km alt.	initiate 2°/s ccw roll reduce thrust to 50%
at pitch angle = 90°	set NAV = ccw prog

The following may occur in either order:

at dynamic pressure (Q) <0.005	increase thrust to 90%
at 2019 50 10 16 25	SRBs burn out and detatch automatically
at Apo = 390	MECO (thrust to 0%)
at altitude = 370	increase thrust to 95%
at Peri = 400	MECO circularize orbit - let spacecraft drift up until Vcen <20 - use main engines to bring Vtan to ref Vo - use rcsp thrusters to reduce Vcen to zero

Docking

Evaluate relative position and orientation of AYSE
Use AYSE docking checklist to dock with AYSE
Press "A" to dock with AYSE once in position (for mirror)

Ceres Transfer Orbit record times and fuel loads for each major step
path is designed to avoid medium to high orbit satellites

target = CERES
set NAV = app targ

at HRT phase angle = 93°	set thrust to deliver 90 m/s^2 (about 29%)
at Vhab-ref = 50000	MECO
at altitude from earth = 50000 km	set thrust to deliver 150 m/s_2 (about 49%)
Vcen targ (R) = $5.00x10^5$ m/s	MECO Alt (earth) approx. 806000 km
set ref=CERES	Vcen targ ® should be $5.21x10^5$ m/s
Path correction burn (1) can commence at once	set NAV = ccw retro apply thrust = +/-10% (approx 20 m/s^2)
at Vtan (R) = 1357	MECO make fine adjustments as needed Vtan and periapsis will not be stable - do not maintain
Path correction burn (2) 50000000 km from Ceres	NAV = ccw retro set thrust to +/-10%
at Vtan=11.7 and peri=650	MECO make fine adjustments as needed periapsis should read approx. 4000 km ccw Vtan and periapsis will not be stable - do not maintain
Path correction burn (3) 1000000 km from Ceres Just prior to retro burn	NAV = ccw retro set thrust to +/-10%
at Peri = 200 (+/- 5 km)	MECO

Retro Burn

at 1000000 km from Ceres	NAV = retro Vtrg
at Acc = 150	set thrust to deliver 150 m/s^2 continuously adjust thrust to keep Acc about 150
at 100000 km from Ceres	set NAV = MAN

Note: Acc will drop as you pass to one side of the planet since Vcen gradually changes to Vtan and Acc is only influenced by Vcen.
Do NOT adjust thrust to match engine acceleration to Acc
Keep engine at thrust level to deliver 150 m/s^2

As the spacecraft gets close to the planet, periapsis will start to decrease.
As if falls below 100 km, begin to reduce thrust so that MECO can occur at Peri = 40 km

at Peri = 40 km	MECO Vhab-ref should be slightly higher than ref Vo NAV = retr Vtrg

Note: Watch speed and altitude as spacecraft falls towards the periapsis.

at Vcen = -5 m/s	increase thrust to reduce Vtan to ref Vo when Vcen = 0 circularize orbit as needed

Carry out Ceres orbit procedures: two orbits.

16-Psyche Transfer Orbit

before 2nd orbit is done	set target = 16PSYCHE set NAV = ccw prog
at HRT phase angle = 100	set thrust to deliver 10 m/s^2
at Vhab-ref = 1000	MECO
at 500 km from Ceres	set target= 16PSYCHE set NAV = app targ set thrust to deliver 150 m/s^2
at Vcen = $5.0x10^5$ m/s	MECO

Path Correction Burn (1)

Can commence at once	set ref = 16PSYCHE set NAV = ccw retro set thrust = +/-10%
at Vtan = 39.5	MECO make fine adjustments as needed Vtan and periapsis will not be stable - do not maintain

Patch Correction Burn (2)

at 50000000 km from 16Psyche	set NAV = ccw retro set thrust to +/-10%
at Peri = approx. 2000 km	MECO make fine adjustments as needed Vtan and periapsis will not be stable - do not maintain set NAV = retr Vtrg

Retro Burn

at Acc = 150	set thrust to deliver 150 m/s^2 make fine adjustments to keep Acc around 150
at 100000 km from 16Psyche	set NAV = MAN
as distance approaches 2000 km	adjust thrust so that Vtan = ref Vo when Vcen = 0 circularize orbit
16-Psyche orbit operations	transfer full fuel load to Hab Undock from AYSE (“A”) back out of AYSE use thrust to take Vtan to zero

Complete orbits are specified in timeline.

16-Psyche surface operations

when final orbit is complete and hab is over the landing site	reduce Vtan to zero accelerate towards 16Psyche to a Vcen of -1000 m/s
at Vcen = -1000	MECO set NAV = depart ref
at Acc increases to 10	set thrust to deliver engine acceleration of 10 m/s^2
at 50 km from 16Psyche	increase thrust to reduce Acc to 5 set thrust to deliver 5 m/s^2
as approaching surface	increase thrust to gradually reduce Acc and Vcen to < 2
at surface contact	MECO

Carry out surface investigation of 16-Psyche landing site.

Depart for earth

2019 66 16 00 00	reduce fuel to 8000 lift off and accelerate straight up to AYSE Dock with AYSE Adjust position to get clear line of sight to earth off to side of 16Psyche
Departure Burn	set target = EARTH set ref = EARTH set NAV = app targ set thrust to deliver 150 m/s^2
at Vcen = -5.00×10^5 m/s	MECO
Path Correction Burn (1)	target = earth ref = earth set NAV = ccw retro set thrust to +/- 10% to bring Vtan to +3000
@ Vtan = +3000	MECO
Path Correction Burn (2) @ 40000000 km from earth	set target = moon set ref = moon set NAV = ccw retro set thrust to +/- 10% to bring Vtan to -70
@ Vtan = -70	MECO
Path Correction Burn (3) @ 1000000 from moon	set NAV = ccw retro set thrust to +/- 1% to bring Peri to 200 km
@ Vtan = +975 & Vtan = 200	MECO set NAV = retr Vtrg

Retro Burn

@ Acc = 150	set thrust to deliver 150 m/s^2 adjust thrust to maintain Acc=150
@ 100000 km from moon	set NAV = MAN
@ Peri = 100	MECO set NAV = retr Vtrg
@ Vcen = -150	set thrust to deliver 100 m/s^2
@ Vtan = 1650	MECO
@ Vcen = -1	use moderate thrust to bring Vtan to ref Vo as Vcen = 0 circularize if needed

Earth Return

	set target = earth set NAV = app targ
@ HRT phase angle = 90	set thrust to deliver 150 m/s^2
@ Vhab-ref = 50000	MECO set ref = earth
@ 150000 km from earth	set NAV = ccw retro set thrust to 10% to bring periapsis to 2000
@ Peri = 2000 km	MECO set NAV to retr Vtrg
@ Acc = 50	set thrust to deliver 50 m/s^2 set NAV = MAN
@ Peri = 404	MECO set NAV = retr Vtrg
@ Vcen = -200	set thrust to deliver 100 m/s^2
@ Peri = 400	MECO
@ Vcen = -20	apply moderate thrust to bring Vtan = ref Vo & Vcen =0 circularize as needed

Landing at OCESS

AYSE verified in stable orbit close to 400 km

Undock from AYSE	set NAV = ccw prog set target = earth load or dump fuel to a load of 4000 kg Press "A" in mirror set NAV = MAN use reverse thrusters to back out of AYSE use lateral thrusters to stay centred in docking port
when HAB is clear of AYSE	Set NAV = depart ref or app targ as needed to adjust orbital alt to 400.00 circularise new HAB orbit set target = OCESS set NAV = retr Vtrg
@ HRT phase angle = 220^o	set target = earth check orbit alt. is still 400 set target = OCESS
@ HRT phase angle = 190^o	deactivate engines set thrust to 20% record Vcrit = ref Vo - 100 m/s as (should be 7623.65 m/s)
@ HRT phase angle = 185.82^o	activate engines
@ V hab-ref = Vcrit	MECO You can make some fine adjustment to refine Vhab-ref since Vhab-ref changes continuously, you only have a few seconds to do this. set target = earth set NAV = MAN rotate ccw to a pitch angle of -115^o pitch will drift back towards -90^o
@ pitch angle = -110.00	press F6 to lock the pitch angle repeat if you are off by more than 0.01^o

The spacecraft will slowly fall into the atmosphere. The pitch angle will generate lift, which will slow the descent and keep the peak drag acceleration (Q) to less than 6 g.

Final Descent: ***after*** peak drag acceleration of approx. 57 m/s^2

@ drag = 50	set NAV= retr Vtrg
@ drag = 40	set thrust to deliver 10 m/s^2
@ drag < 15	set thrust to deliver 13 m/s_2
as drag falls to less than 1	set thrust to match engine acceleration to Acc
@ Vtan < 0.01	set NAV = MAN
as altitude approaches 1 km	increase thrust to reduce Acc the goal is to near Vcen = -2.0 m/s below 0.5 Alt. adjust thrust to maintain Vcen just below -2.0
@ touchdown	MECO

If you are not above OCESS once Vtan < 1 then increase thrust to transition to a hover.
set NAV = MAN
tilt the HAB toward OCESS to start a lateral drift towards it.
increase thrust while tilted
reduce thrust to maintain hover once back to vertical

A steady slight tilt will be needed to maintain a high speed lateral drift.

total mission time: 28 days (672 hours)