

# OCESS Procedure Manual

## 0.0 GUIDE AND DEFINITIONS

### 0.1 GENERAL GUIDE

**0.1.1 General** This manual is primarily for pre-mission training and secondarily as an in-mission reference.

### 0.2 DEFINITIONS

**0.2.1 Alpha-class emergency:** An incident outside of the parameters of the Simulation.

*Immediately inform teacher advisor or designate.*

**0.2.2 Beta-class emergency:** An incident within the parameters of the Simulation.

**0.2.3 AYSE Drive:** The power and engine unit that the Habitat docks with for interplanetary travel.

**0.2.4 Mission Control:** (MC) The Launch and Flight Operations control centre of the OCESS.

**0.2.5 Habitat:** (HAB) The Hawking II, planetary transit and habitation vehicle used by the OCESS.

**0.2.6 EVA:** Extra-Vehicular Activity, consisting of space walks and surface excursions.

**0.2.7 IVA:** Intra-Vehicular Activity, consisting of moving around the interior of the Habitat in full EVA equipment. This is generally rendered necessary by environmental leaks, depressurization, or hazardous materials spills.

**0.2.8 TCS:** The Tachyon Communication System, our faster-than-light communication system; it does not need relays due to its fundamental nature. Is composed of the TCU (Tachyon Control Unit) and TCER (Tachyon Control Emission and Reception) which are the Habitat and Mission Control devices, respectively. Tachyon collector dishes are used for reception. The radios (headsets) and digital VOX (handset), telemetry, and AUXCOM (text messaging), all use this carrier system.

### 1.0 Mission Control Staffing

Asterisk denotes staff positions that are normally filled at all times.

Other positions may only be staffed during critical phases of flight.

**MOD\*:** **Mission Operations Director** (teacher advisor or adult designate); in charge of safety.

**FLIGHT\*:** **Flight Director;** MC staff member in charge of mission activities.

**GUIDO\*:** **Guidance Officer;** officer who monitors flight profile and testing alterations to flight profile.

**GNC:** **Guidance, Navigation and Control systems engineer;**  
Officer who monitors telemetry, including engineering systems and navigation.

**INCO\*:** **Integrated Communications Officer;**  
Officer in charge of network, cameras, auxcom, and all other computer systems

**EECOM\*:** **Electrical, Environmental, and Consumables Manager;**  
in charge of monitoring and changing the environmental systems, doors, and all external environmental threats such as atmosphere and radiation. Also in charge of monitoring and evaluating astronaut's cumulative radiation dose.

**FIDO:** **Flight Dynamics Officer;**  
Officer in charge of planning the flight profile and approving any changes to the profile.

**FAO:** **Flight Activities Officer;**  
Officer in charge of drawing up plans and schedules for all astronaut activities.

**LOGGER:** MC staff member in charge of recording mission logs. May include making video tapes of camera signal.

**CAPCOM\*:** MC staff member in charge of voice communications with HAB spacecraft.

**AUXCOM:** MC staff member in charge of network communications with HAB spacecraft.

**1.0.1 Astronaut Staffing:** Although the Astronauts do not have the same staffing structure as mission control, they will be completing many of the same functions. The astronaut duty stations and functions are set out in section 2.0 and will be detailed in the Astronauts' PCAP schedules. Some overlap of duties is necessitated by the number of stations. Duty station assignments are drawn up by FAO prior to launch, but MCOM is responsible for assigning duty stations as needed during the mission.

**MCOM:** Mission Commander; in charge of all operations onboard the spacecraft.

**Pilot:** Astronaut in charge of carrying out flight operations flight operations.

**Copilot:** Astronaut assisting the pilot by assessing the trajectory and any changes to the flight plan.

**EECOM:** Astronaut carrying out EECOM duties onboard the spacecraft.

**EMPROP:** Astronaut controlling **Electrical, Mechanical, and Propulsion systems** through the engineering software.

**MMCAS:** **Maintenance, Mechanical, And Crew Systems** astronaut. Usually the Tech Specialist.  
Astronaut responsible for carrying out all repairs and modifications to systems.

**CAPCOM:** Astronaut responsible for voice communication with mission control.

**AUXCOM:** Astronaut responsible for data communication with mission control.

## **1.1 FLIGHT DIRECTOR**

**1.1.1** The Flight Director is responsible for all flight operations and is in charge of Mission Control during all mission phases and emergencies.

**1.1.2 Standard Flight Procedure:** The Flight Director normally does not communicate directly with the Astronauts during normal Mission Control operations. Only in the event of the Capcom officer having technical difficulty or in an emergency where direct clarity of the requested order is needed should the flight director directly communicate with the astronauts. All communication is the responsibility of INCO (P1.3) and CAPCOM (P1.2). The Flight Director can order timetable changes, command EVA operations, authorize recommendations by other station officers, etc. However, the Flight Director's authority is overridden by direct government or OCESS Command orders issued to the Habitat Commander whenever his/her orders conflict directly with government's/Command's orders (see P5.3.1). Under no circumstances is the Flight Director to leave Mission Control during his/her shift, whether an emergency is occurring or not.

**1.1.3 Emergency Procedures:** The Flight Director is responsible for dealing with all Beta-class Emergencies and is fully within his or her authority to order a mission abort.

In the event of an alpha emergency, the teacher advisor or adult designate in mission control will direct all responses to the emergency. In an alpha emergency, the job of the flight director, Mission Control Commander (if present in MC), and Habitat Mission Commander is to report the situation accurately to the teacher advisor or designate and ensure that all commands from the adult in charge are followed (see 1.1.3.2).

**1.1.3.1 Acting Flight Director:** Before leaving mission control for any reason, including the end of his or her shift, the flight director must either turn over responsibility to another person who assumes the role either of acting flight director or flight director. The only difference between flight director and acting flight director is that the acting director automatically relinquishes the duty upon the return of the flight director.

**1.1.3.2 Real fire emergencies:** For all critical emergencies (and all Alpha emergencies, whether critical or not) follow P4.3

## **1.2 CAPCOM**

**1.2.1** The Capsule Communications Officer is responsible for all primary voice communication with the Habitat.

**1.2.2 Standard Flight and Emergency Procedure:** Under normal Mission Control operations, the Capsule Communications Officer communicates all information relayed from other stations, including the Flight Director, to the Habitat Capcom. Under no circumstances is the Capcom to make independent decisions concerning launch or flight operations. The Capcom also relays the astronauts' current jobs to the Habitat at the beginning of each scheduled shift.

**1.2.3 Communications Protocols:** Whenever possible, the Capcom is to use the following expressions in communications with the Habitat Capcom:

Roger / Copy: Acknowledged.

Negative: No.

Beta Evacuation: Modular evacuation.

Over and Out: Communications finished.

Affirmative: Yes.

Alpha Evacuation: Full Habitat evacuation.

Over: Message finished.

When speaking on radio, speak slowly, clearly, and with lower than normal voice pitch. When using the Digital VOX system, normal conversational voice can be used, but clarity of voice and wise choice of words still are important.

## **1.3 INCO**

**1.3.1** The Instrumentation and Communications Officer is responsible for all secondary computer-based (text messaging) communications (AUXCOM) with the Habitat, camera systems, the TCS, mission timer, and the CMES server and computer network. Specific details on the network and CMES server can be found in the OCESS Network Procedures Manual. The network manual also contains instructions for starting EECOM, ORBIT, and other networked software.

**1.3.2 Standard Flight and Emergency Procedure:** INCO is to constantly monitor and maintain all primary and secondary communications between Mission Control and the Habitat: the camera system, Auxcom, and Capcom (TCS). This officer is also responsible for logging all significant mission events. In all emergencies, Auxcom must be monitored closely, as CAPCOM could lose contact without warning.

**1.3.3 Logging Procedure:** All Log entries must have the current Mission Time appended to their entries. The INCO incarnation of CMES should do this automatically. All CAPCOM messages, Experiment Data, mission status changes, and Habitat status changes must be logged. The INCO shall log, in short, all direct messages. The INCO should also be prepared to access prior entries if requested by other Mission Control or Habitat staff.

**1.3.4 Logger:** Flight director may appoint another MC staff member to record and save mission logs during critical phases of the mission.

**1.3.5 Camera Operations:** The INCO must change workstations to Stonehenge when a camera change is requested. To change which camera a TV displays, right-click on the TV in the Hub display and go to Properties; click on the second tab; change the 'video-on-idle' setting to the name of the camera which has been requested. Generally, requests for these changes comes from either the Mission Commander or Flight Director.

## **1.4 EECOM**

**1.4.1** The Electrical and Environmental Command Console Officer is responsible for the maintenance of the environmental parameters of the Habitat: temperature, O<sub>2</sub>, N<sub>2</sub>, etc. EECOM is responsible for observing video images of astronauts for signs of health problems. EECOM also is responsible for monitoring AIRLOCK pressure during docking/undocking and EVA egress and ingress.

**1.4.2 Standard Emergency Procedures:** The EECOM officer is to monitor Habitat electrical systems, pressure, gas balance, O<sub>2</sub>, N<sub>2</sub>, etc. Should any alarming change occur, the EECOM is to notify the Flight Director in order to make a decision regarding the change. The EECOM is responsible for then instituting remote changes to the Habitat systems as instructed by the Flight Director when the habitat crew is unable to make these changes themselves. EECOM should not to make any changes without prior authorization.

**1.4.3 Computer Interfacing Procedure:** The EECOM system monitors atmospheric conditions inside the habitat modules. The specific conditions are total pressure; the partial pressures of N<sub>2</sub>, O<sub>2</sub>, CO<sub>2</sub>, Ar, H<sub>2</sub>O; and the levels of dust, dangerous chemical fumes, and biological hazards. EECOM also monitors the status of the doors. Using the EECOM control software, the MC or habitat staff can identify the onset of abnormal conditions and take steps to correct them.

To modify the conditions in a module (compartment), that module must be selected using the up/down arrow keys. The module is highlighted on the graphical display as is the gas data line for that module. Hazardous conditions in a module are indicated by a yellow color on the graphical display. Critical or lethal conditions are indicated by a red color.

### **1.4.3.1 Door Warning Indicators**

Doors with dangerous pressure differences are indicated by a red background; safe doors are indicated by a white background. Doors that are not functioning properly and which may fail are indicated in red; those functioning properly are shown in white.

Doors that show potential malfunctions should be checked and physically adjusted. After adjusting the door, wait to see if the warning indication returns to normal. If not, and if the door has a dangerous pressure difference, consider evacuating the compartment, sending in a tech specialist, and adjusting the compartment pressure so as to be able to open the door.

During emergency situations, EVA procedures, and other unusual situations, Habitat and Mission Control EECOM officers must approve all opening and closing of doors.

### **1.4.3.2 Venting and Re-pressurization**

The atmosphere within a module can be vented or re-pressurized. Re-pressurization involves the introduction of a normal atmospheric air mixture. As such, hazardous contaminants can be removed by venting air and re-pressurizing the compartment. However, this method will not be effective if the source of the contaminants have not been removed first. Venting can be manual ('-' and '+' keys) or automatic (venting stops at zero pressure, re-pressurization stops at 101.32 kPa) (F11 and F12 keys). As air will move through open doors from high pressure to low pressure modules, air can be moved through between modules by selectively opening doors and adjusting air pressure. This can be useful for containing contaminants within particular modules. Venting or re-pressurizing of a module is indicated by a 'v' or 'p' symbol in the upper-right corner of that module on the graphical display. Two levels for each are indicated by upper- and lower-case letters.

### **1.4.3.3 Correcting Atmospheric Conditions**

The levels of CO<sub>2</sub>, water, and dust are maintained using a system of scrubbers, filters, and supply systems. These systems can be overcome by extreme conditions within a module: heavy construction activity, too many crew-members working in one module, or activities involving open water. When this occurs, CO<sub>2</sub>, water, or dust levels may begin to climb. If this happens, supplementary systems can be manually activated using the EECOM system to correct the imbalances. However, the cause of the problems should be investigated and corrected, if possible:

- evaluate the way the compartment is being used
- check for any open containers or spills
- check for any leaks in pressurized gas pipes
- check that the primary CO<sub>2</sub> scrubbers, humidifiers, and dust filters do not need their cartridges or filters replaced

Keys for the supplementary CO<sub>2</sub>, water, and dust management systems are indicated in the EECOM display. The functioning of these supplementary systems is indicated on the panel below the primary gas data panel.

### **1.4.3.4 Mission Control EECOM**

The EECOM control system in mission control has most of the abilities to control the atmosphere and door systems as are present in the habitat version of the system. MC EECOM can make changes to the system in the habitat, but the control inputs made from the habitat console take precedence.

### **1.5 GUIDO, GNC, and FIDO**

The Guidance Officer monitors telemetry data from the ORBIT5S flight management software at the pilot station in the habitat. Telemetry is monitored using two programs: ORBIT5Sm, a graphical interface, and ORBIT5St, a non-graphical interface which allows simultaneous monitoring of all hab and AYSE drive systems. The primary responsibilities of GUIDO are to ensure that the flight path of the hab conforms to the planned path, that the planned flight path does not put the habitat into danger, and to act as a backup monitor for any system alarms. When requested to by the flight director or the habitat pilot, GUIDO can stop telemetry transfers and use ORBIT5Sm to run and record orbit scenarios. GUIDO also can calculate data on low-power and high-power transfer orbits (using TRANSORB or ORBCALC respectively) to assist the habitat pilot in planning orbit changes. ORBIT5Sf is a program that can be used to fast-forward to a new time point in the orbital database.

The Guidance Officer is responsible for monitoring all gravitational, orbital, and environmental effects on the trajectory of the AYSE Drive and Habitat. GUIDO shall assist the HAB pilot in following all flight procedures via CAPCOM.

The pilot is responsible for carrying out all flight procedures and following the mission profile. While the pilot also is responsible for complying with all directives from the habitat commander and flight director, it is the responsibility of the pilot to ensure that all actions taken are consistent with the safety of the crew and goals of the mission.

GUIDO normally is assisted by GNC (Guidance Navigation and Control systems engineer) who operates the ORBIT5St, TRANSORB, and ORBCALC software.

During critical phases of the mission, the Flight Dynamics Officer (FIDO) takes charge of decisions regarding the flight path of the spacecraft. GUIDO and GNC report to FIDO and are responsible for gathering the data needed to assess the performance of the spacecraft.

#### **1.5.0.1: Planning**

FIDO, GUIDO, and the pilots are responsible for planning, and where necessary recording, the flight profile for all phases of the mission prior to launch.

If any updates to the flight profile are necessary after launch, FIDO and GUIDO are responsible for planning, testing, and recording new flight profiles using Orbit5Sm. These profiles must then be documented and transmitted over Auxcom to the habitat spacecraft. New flight profiles must be approved by the pilot and co-pilot prior to being implemented. Generally, the pilot not flying is responsible for evaluating any new flight profiles. During these times, GNC assumes primary responsibility for all telemetry.

### 1.5.1 ORBIT5S

Orbit5S is the primary piloting software program used in spacesim at the present time. It models the position, velocity, and gravity of the sun, all of the planets, most of the larger moons, and many other smaller objects within our solar system. It manages all of the pilot controls that allow the spacecraft to be navigated to any of the modeled objects and either enter into an orbit around them or land on them (if they have a solid surface). Orbit5S is a 2-dimensional simulation. Ignoring the third spatial dimension keeps the complexity of piloting a spacecraft to a manageable level. You won't have to take a year off school to perfect your skills.

Orbit5S is just one component of the spacesim simulation network. Most of the other software components use output from Orbit5S, but Orbit5S does not need most of them to run itself. Output from the engineering software, Orbit5SE, is necessary for the proper functioning of Orbit 5S. Orbit5SE is described in section 1.6. Orbit5S will run, although not update its fuel state, as long as Orbit5SE has been started and has had the engine systems turned on properly. Once this has been done, the Orbit5SE software can be closed. Orbit5S can then be started and it will run using the last data output file from Orbit5SE.

In order to use the orbit software effectively, it is important to understand the intricacies of controlling a vehicle in space and, in particular, a vehicle in orbit. In an environment without friction or drag, but with ever-changing gravity, many of the intuitive assumptions with which we have become accustomed will not only not work, but may cause serious accidents to occur.

#### 1.5.1.1 Motion in Space

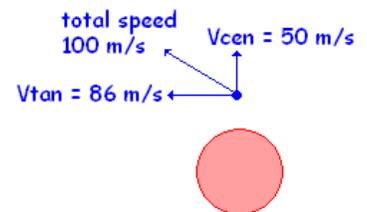
In space there is no set frame of reference (such as the lines of latitude and longitude that we use for compass directions on earth). However, we can use what ever planet or moon we are in orbit around or travelling to as a temporary reference point. Even with a reference point, the compass directions have no meaning high above the surface of a planet.

In our 2-dimensional simulation, there are two components of direction that are important to us. We use them for describing speed, distance, and engine thrust. One component is direction towards or from the planet (in-and-out, or centripetal direction). This can be towards (negative) or away (positive). The other direction is side-to-side relative to the planet (the tangential direction). This usually is described as being counter clockwise (ccw) or clockwise (cw). Most objects in our solar system rotate and revolve (move around another object) in a counter clockwise direction. Because of this, counter clockwise orbits around a planet are normal for spacecraft operation.

Motion must always be described in relation to some planet or other object. The Orbit5S software allows you to specify two different such objects at the same time: the reference object (usually the one about which you are in orbit) and the target object (usually your destination). The velocities and distances displayed by the software always are in relation to one or the other of these two objects. It is important to keep track of which object has been selected for the target and reference, or you may misinterpret the data displayed by the software.

It is very rare that a spacecraft moves only towards a object (except when landing) or only sideways with respect to an object (except while in a circular orbit). More often, the motion is a combination of the two. It usually is useful to consider each of these components of motion separately, however, when planning different orbital manoeuvres.

Consider the situation shown to the right. A spacecraft is moving away and counter clockwise relative to a planet. The total velocity is 100 m/s (up and to the left as drawn). You could consider the centripetal and tangential velocities separately (the ORBIT5S displays them for you). In this case, the tangential velocity ( $V_{tan}$ ) is 86 m/s counter clockwise and the centripetal velocity ( $V_{cen}$ ) is 50 m/s outward. These two velocities add up to the 100 m/s total velocity that the spacecraft actually has. Knowledge of separate velocity components is useful in many circumstances, such as determining how to circularize a non-circular orbit (see below).



Unlike on an planet or in an atmosphere, all changes in the velocity of an object must be accomplished using the engines. This includes speeding up, slowing down, **and** changing direction. For example, if you want to slow down, you must fire your engines to push the spacecraft in the direction opposite to that in which you are presently travelling. If you want to make a 90° turn to the left, you must use the engines to both push the spacecraft backwards to stop motion in your current direction and push the spacecraft towards the direction that you wish to travel. This is explained in more detail in section 1.5.3

### 1.5.1.2 Motion in Orbit

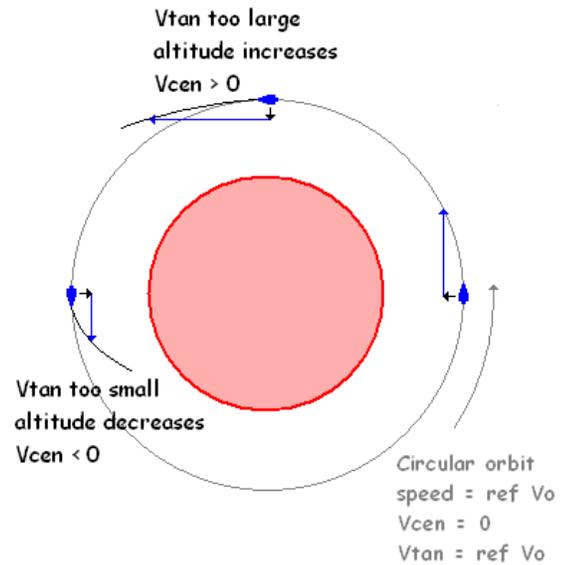
In orbit, an object is always falling towards the Earth (or what ever other planet about which you are in orbit). This is because of gravity. In a low-earth orbit, there is almost as great a force of gravity as on the surface of the earth. This should seem reasonable, because compared to the radius of the earth (6370 km) being only 300 km farther up should not make much difference.

Spacecraft can carry only so much fuel; not enough to counter-act gravity for more than a few hours (even our spacecraft). So, they avoid falling back to earth by moving sideways fast enough to keep missing it! On the diagram to the right, in each time interval, the spacecraft on the right falls a certain distance (black arrow). If, in the same time interval, it moves sideways just right distance (the blue arrow) to end up still at the same height above the earth.

Gravity does decrease the higher above the earth you go. Thus, you need less sideways speed to stay in orbit when you are farther from the earth.

The correct tangential speed ( $V_{tan}$ ) for a given orbital height is **ref  $V_o$** . Since the height does not change in a perfectly circular orbit,  $V_{cen}$  should be zero.

As long as the orbit is above the atmosphere, there is no drag to slow the spacecraft down and the  $V_{tan}$  speed will remain constant. Thus, as we will see in section 1.5.2, the job of the engines in getting a spacecraft into orbit is to: 1) push the spacecraft up to the correct altitude, and 2) to accelerate it sideways to the correct ref  $V_o$  speed. Once this is done, the engines are not needed unless we wish to make adjustments to the orbit.



### Non-Circular Orbits

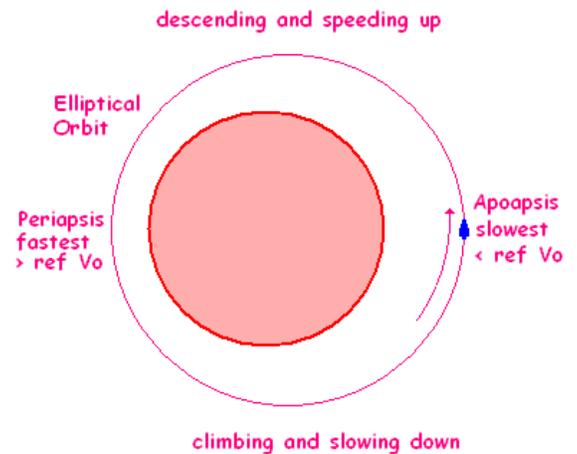
If an orbit is not circular (elliptical), its speed will change continuously.

For example, if the  $V_{tan}$  is too slow (less than ref  $V_o$ ), the spacecraft will not move sideways far enough to stay at its altitude and it will start to descend. Almost all orbits are somewhat elliptical.

As the spacecraft descends, it speeds up because it is moving with gravity.  $V_{tan}$  gets faster and faster the lower it goes.  $V_{cen}$  starts to become negative (indicating decreasing distance from the planet) and gets more negative as the rate of descent increases. Eventually  $V_{tan}$  gets so high that the spacecraft starts moving sideways enough to counteract its descent, and  $V_{cen}$  starts to get less negative (the descent rate slows down). When  $V_{tan}$  is large enough, the descent stops ( $V_{cen}$  is zero again) and the spacecraft is at the lowest point of its orbit (the **Periapsis**). Note that the periapsis is on the opposite side of the planet from the apoapsis.

At the periapsis point, the spacecraft, having been accelerated by gravity to such an extent, is now travelling faster than the ref  $V_o$  for that altitude. Because of this, it moves sideways farther than needed to maintain its orbital height, and begins to climb.

As it climbs, it moves against gravity, so it starts slowing down. Thus,  $V_{tan}$  begins to decrease.  $V_{cen}$  is positive, since the distance from the planet is increasing. Eventually,  $V_{tan}$  decreases so much that the rate of ascent begins to decrease ( $V_{cen}$  becomes less positive). The spacecraft will reach its high point (**apoapsis**) at about the same place as it was before, having slowed down to the same speed it had before (less than ref  $V_o$ ) and the whole process starts over again.

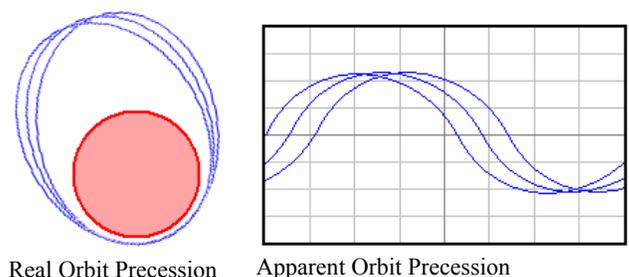


This pattern will repeat continuously, as long as the periapsis is above the atmosphere. If not, drag will slow the spacecraft a little more at each periapsis and each periapsis and apoapsis will be a little lower. Eventually, the orbit will intersect the surface of the planet and the spacecraft will crash.

### Real and Apparent Orbit Precession

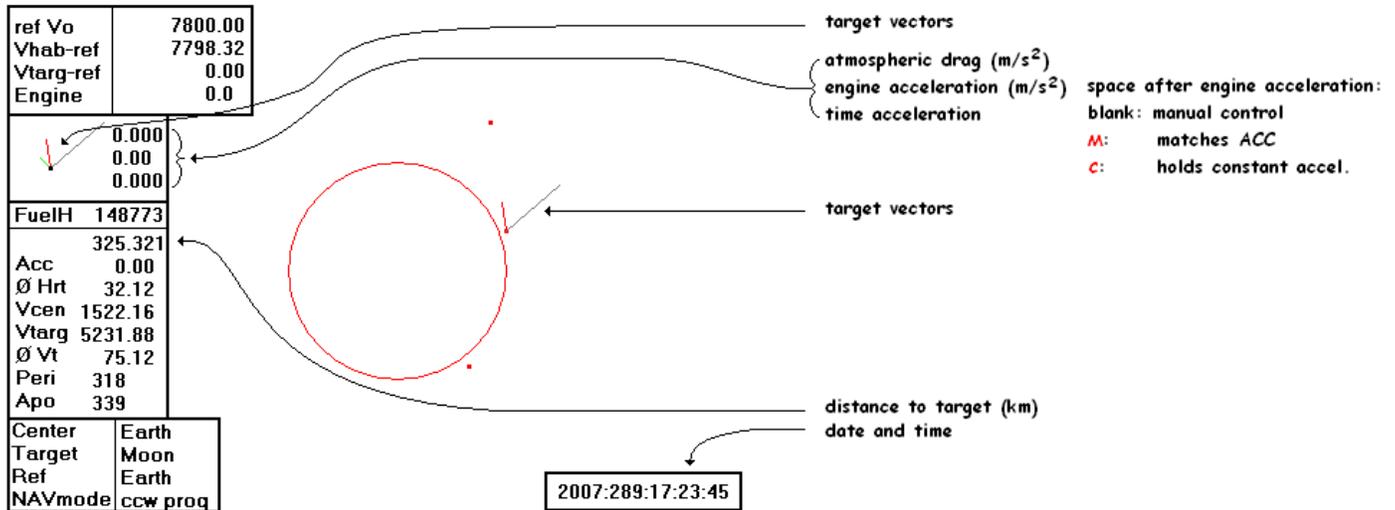
Another peculiarity of an elliptical orbit is that the position of the periapsis and apoapsis shifts slightly, precesses, on each orbit. This precession is predicted by Newton's laws of motion. It only is very noticeable in orbits that are very elliptical.

The longitudinal shift in the orbits of spacecraft and satellites when viewed against the earth is not due to orbit precession. Rather, it is the result of both the latitudinal tilt (inclination) that most real orbits have and the fact that as a satellite orbits the earth, the earth also is rotating at a different rate under it. In the time it takes most satellites to complete an orbit (about 100 minutes), the earth rotates about 25°. We have real precession, but not apparent precession in our simulation as it is only 2-dimensional and our planets do not rotate.



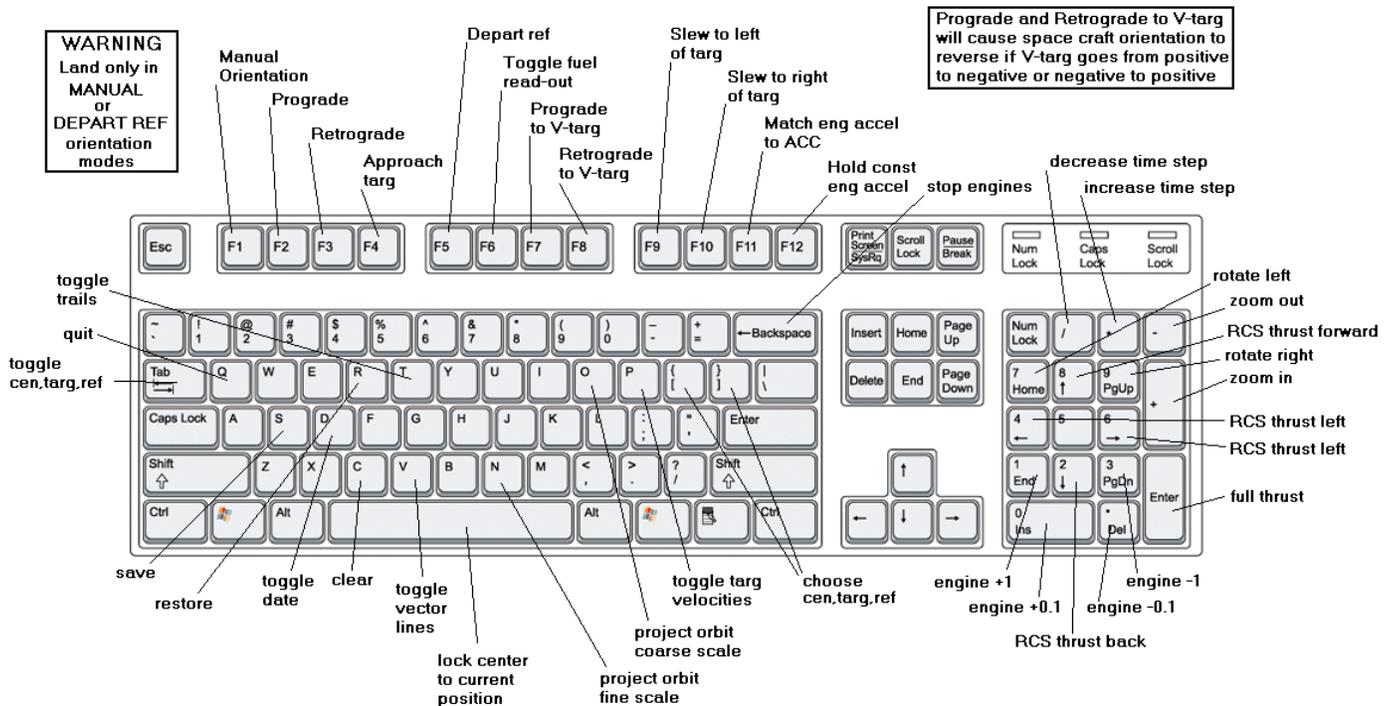
### 1.5.1.3 ORBIT5S User Interface

All information in Orbit5S is displayed on a single user interface screen.



All controls are manipulated using the computer keyboard.

### Keyboard Controls for ORBIT5S



ORBIT5S controls are lower case. CEN, TARG, and REF choices are upper case.

ORBIT5Sm extra controls  
 f: extended orbit projection  
 w: toggle fuel read-out

x: toggle telemetry

y: record path  
 z: load and display path  
 Z: display path

### 1.5.1.4 ORBIT5S Controls (Case Sensitive)

Engines: **Ins** -0.1 % \ Reverse Engines  
**Del** +0.1 % **BckSp** Stop Engines  
**End** -1.0 % **ENTER** Full Thrust  
**PgDn** +1.0 % **Arrows** Vernier Thrusters (up=ahead, down=back, left, right)  
**F11** match engine accel. to ACC **F12** maintain constant engine accel.  
**F6** toggle fuel state read-out

Navigation: **Home** rotate ccw **PgUp** rotate cw **F1** manual orientation  
**F2** ccw prograde **F3** ccw retrograde **F4** approach targ  
**F5** depart ref **F7** proVtarg **F8** retro Vtarg  
**F9** slew left of target (toggles between left (-) and no slew)  
**F10** slew right of target (toggles between right (+) and no slew)  
**v** Toggle approach to target vector & approach to target velocity vector ON/OFF  
**TAB** Toggle Select: CENTER, TARGET, REFERENCE  
Select objects from the list below **or**  
Scroll through items using '[' and ']' keys  
**p** display centripetal and tangential speed relative to target object  
**o/n** project orbit path relative to reference object (long range/short range)  
this shows the path that the spacecraft would take relative to the reference object *if*  
the engines were shut off at that point in time. It is less accurate if there are any other  
objects with significant gravity nearby.  
**space** lock center position at current habitat position relative to target object

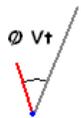
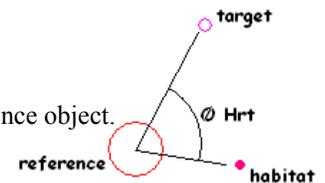
#### Solar System Objects for selecting target, reference, and center of view (case sensitive)

0	Sun	=	Io	J	Triton
1	Mercury	>	Europa	K	Charon
2	Venus	?	Ganymede	L	Habitat
3	Earth	@	Callisto	M	Ceres
4	Mars	A	Tethys	N	Comet Borrelly
5	Jupiter	B	Dione	O	Vesta
6	Saturn	C	Rhea	P	AYSE drive Module
7	Uranus	D	Titan	Q	Sedna
8	Neptune	E	Iapetus	R	Quaoar
9	Pluto	F	Ariel	S	ISS
:	Moon	G	Umbriel	T	Detachable Habitat Module
;	Phobos	H	Titania	U	OCESS Launch Pad
<	Deimos	I	Oberon		

Other Controls **+** Zoom In **-** Zoom out  
**d** display time **`** Toggle data display on/off  
**t** display trails **u** display colour-coded trails  
**\*** increase frame rate **/** decrease frame rate  
**\*\*\*do NOT use frame rate greater than 2 seconds when in a low altitude orbit\*\*\***  
**q** End program **s** Save data to a file  
**r** Restore data from a file (timed backup file is called "ORbackup")  
**c** refresh screen

### 1.5.1.5 ORBIT5S Screen Data Display

ref Vo:	displays the correct orbital speed (m/s) for the current distance from the reference object.
Vhab-ref:	displays the total speed (m/s) of the habitat relative to the reference object (magnitude only, not direction) this will match the ref Vo when in a stable, circular orbit
Vtarg-ref:	displays the speed (m/s) of the target relative to the reference object (will be zero if targ = ref).
Engine:	Current engine thrust in percent of maximum
Target Vectors:	grey vector (approach to target) shows direction towards centre of the target object. red vector (approach to target velocity) shows the habitat velocity direction relative to the target object green vector shows orientation of spacecraft; the direction that a positive engine thrust will push the spacecraft
Drag:	Shows the acceleration due to atmospheric drag in $m/s^2$ (yellow when parachute is deployed)
Engine Accel:	Shows the acceleration of the habitat or AYSE drive resulting from the engine thrust in $m/s^2$ If followed by a blank space, this indicates that the thrust is manually controlled If followed by 'M' this indicates that the engines are matching their thrust to the current ACC to the target If followed by 'C' this indicates that the engine acceleration is being held constant. - in manual mode, engine acceleration increases at constant thrust as fuel is used up and total mass decreases The numeric display is orange when the solid rocket boosters are active.
Frame Rate:	Shows the simulation frame rate (0.125 and 0.250 are real time, all others are accelerated)
Fuel:	Displaces the current fuel load can toggle between habitat fuel (H), AYSE drive unit fuel (A), and the vernier thruster pressure reserve (RCS)
Distance:	Displays distance (in km) to the target object.
Acc:	Displays the engine thrust needed to bring the habitat to a stop at the surface of the current target object. Only displays correctly when habitat is moving directly or nearly directly towards the target object. This reading takes into account: gravity of target object distance to target object's surface relative speed toward target object
$\theta$ Hrt:	Displays the angle between the habitat and target relative to the center of the reference object.
Vcen:	Shows centripetal speed (in-and-out speed) (m/s) relative to <b>target</b> object.
Vtan:	Shows tangential speed (side-to-side speed) (m/s) relative to <b>target</b> object Should be near <b>zero</b> when in a circular orbit and when the target is the same as the reference.
$\theta$ Vt:	Angle between the direction to target vector (grey) and the velocity to target vector (red)
Peri:	Displays the projected minimum altitude (km) from <b>reference</b> object in the next 90 minutes. Periapsis is defined as the low point of an orbit.
Apo:	Displays the projected maximum altitude (km) from <b>reference</b> object in the next 90 minutes. Apoapsis is defined as the high point of an orbit.
Center:	The object on which the display is centered
Target:	The destination object In many cases, this will be set to the same as the reference object to facilitate certain orbit calculations
Reference:	The object for which orbital statistics are calculated.
NAVmode:	Displays the current orientation mode: Manual: orientation remains fixed in the inertial frame unless manual orientation controls are used ccw prog: maintains correct orientation for counter clockwise (prograde) orbit ccw retro: maintains correct orientation for a clockwise (retrograde) orbit App targ: maintains an orientation directly towards the target object Deprt ref: maintains an orientation directly away from the reference object pro Vtrg: maintains an orientation in the same direction as the target velocity vector ret Vtrg: maintains an orientation directly opposite the target velocity vector If preceded by a '+', the target vector points to the right side of the target (right slew) If preceded by a '-', the target vector points to the left side of the target (left slew)
Date:	Displays year: day: hour: min: sec



### 1.5.2 Planetary Launch Procedure

- 1) Select the current planet as **reference** and **target** object (see section 1.5.4)
- 2) Select habitat as center position ("L")
- 3) Press <space> to lock current center position.
- 4) Press F5 for automatic **depart ref** orientation.
- 5) Press v to activate approach velocity vector if desired.
- 6) a) Consult GUIDO for lead angle when launching to intercept orbiting target.  
e.g. to intercept ISS from earth, lead ISS by 18°.
- 7) Set engine for liftoff.
- 8) Adjust thrust to exceed local gravity by a factor of 3 or more (at least 30 m/s<sup>2</sup> on earth), if possible.
  - a) on low gravity planets, HAB engines are sufficient to achieve desired thrust.
  - b) on higher gravity planets, such as the earth, one of two strategies must be used.
    - i) depart with the minimum fuel load to achieve the mission (a few thousand kilograms if docking with AYSE)
    - ii) use the solid rocket boosters (SRBs).

Solid rocket boosters with main engines will produce more than a 30 m/s<sup>2</sup> acceleration with a full fuel load.

#### WARNING

Once solid rocket boosters are ignited, they cannot be stopped - the HAB is going to fly!

SRBs are exhausted in 3 minutes. They do **NOT** operate for long enough to achieve a stable orbit.

*Always run main engines at local gravity to test their function before igniting the SRBs.*

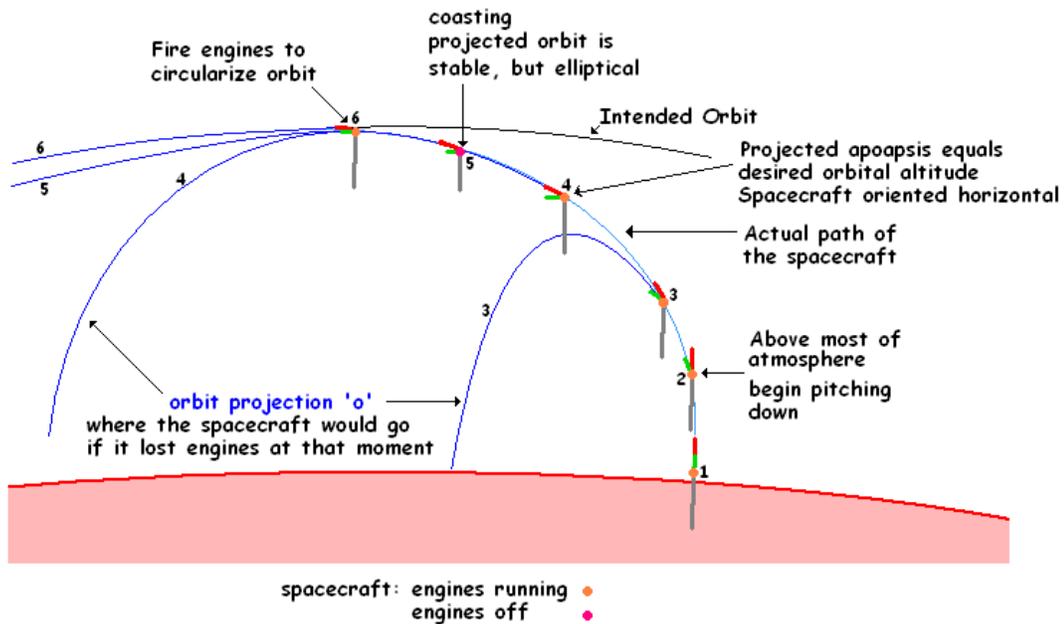
- 9) Press F1 for manual orientation control once clear of the surface.
- 10) Launch profile: GUIDO will provide an exact profile for a given departure:
  - maintain near vertical ascent until clear of most of the atmosphere,
  - gradually pitch towards horizontal to achieve ref Vo while maintaining vertical speed until ref Vo is reached
  - ref Vo will not be reached until apoapsis, but tangential speed must be built up as fast as possible.

**It is safer to establish a stable low orbit and increase it later than to launch directly to a high orbit.**

**In a launch directly to high orbit, ref Vo and a stable orbit are reached much later.**

**If engines fail before ref Vo is reached, a crash landing is likely.**

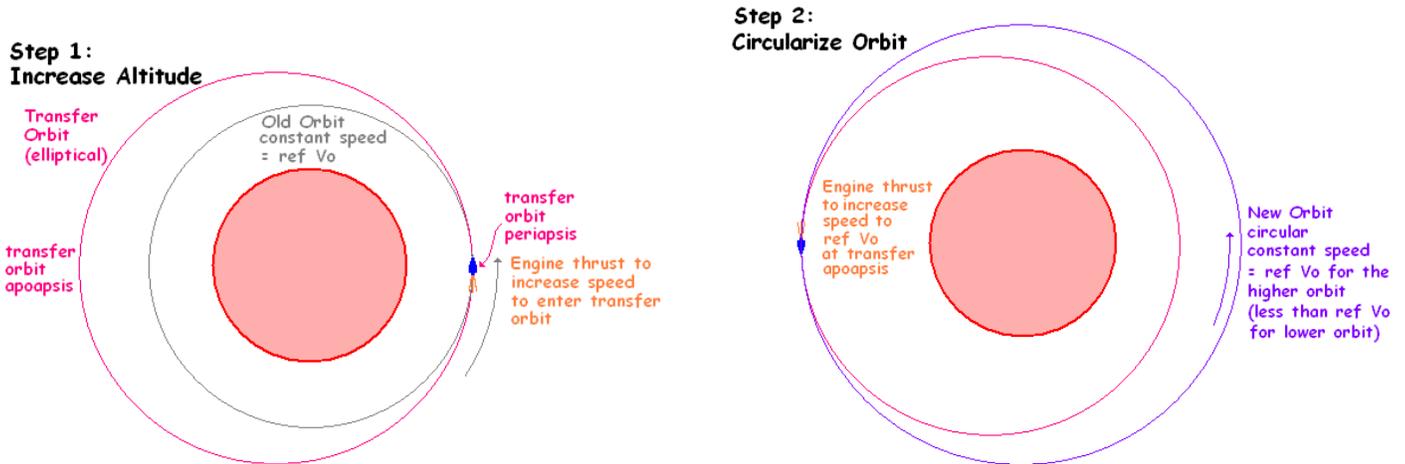
- 11) When projected apoapsis is within 10% of the desired apoapsis, select NAVmode ccw prog or ccw retro depending on orbit.
- 12) When projected orbit is stable (will not intersect earth's surface) stop engine.
- 13) When desired apoapsis is approached (Vcen falls below approximately 200 m/s), set engine thrust until Vtan equals Vref.
- 14) At apoapsis, select NAVmode **dep ref**; use positive or negative engine thrust to zero out Vcen.
- 15) Select NAVmode **ccw prog**; use positive or negative engine thrust to achieve Vtan equal to ref Vo.



### 1.5.3 Adjusting an Orbit

#### 1.5.3.1 Increasing the Altitude

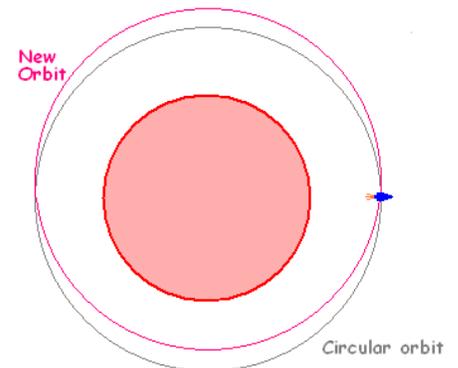
- 1) Set both the target and reference objects to be the planet about which you are in orbit.
- 2) Orient the spacecraft in the direction of the orbit (green vector should line up with the red vector).
  - select NAVmode ccw pro (Press F2) for a prograde (counter clockwise) orbit
  - select NAVmode ccw retro (Press F3) for a retrograde (clockwise) orbit.
- 3) Set engine thrust to produce a 5 to 10  $m/s^2$  acceleration (you can use greater acceleration as you gain experience) (Step 1).
- 4) GUIDO will give you data on acceleration and duration of engine thrust.
  - If GUIDO data is not available, continually press 'o' to project your new orbit while the engines are on.
  - once the apoapsis projection equals the desired orbital altitude, stop engines
  - reduce thrust as desired apoapsis projection is approached to avoid overshooting
- 5) Coast with engines off until spacecraft climbs to apoapsis. This elliptical orbit is the **transfer orbit**.
- 6) Just before apoapsis, set engine thrust to accelerate  $V_{tan}$  to match  $ref V_o$ . This will circularize your orbit (Step 2).



This method of increasing altitude is slow, but it has the advantage of safety. If engines fail after the first engine burn, the orbit will still be stable, although elliptical. The periapsis of the transfer orbit will be no lower than the original orbit.

If you try to increase altitude by firing the engines to push directly away from the planet, you will reach apoapsis in one quarter of an orbit, rather than one half. However, the periapsis of this elliptical orbit will be much lower than that of the original orbit, perhaps dangerously close to the atmosphere or surface of the planet.

**If engines fail after the first burn using this method, a crash landing is possible.**

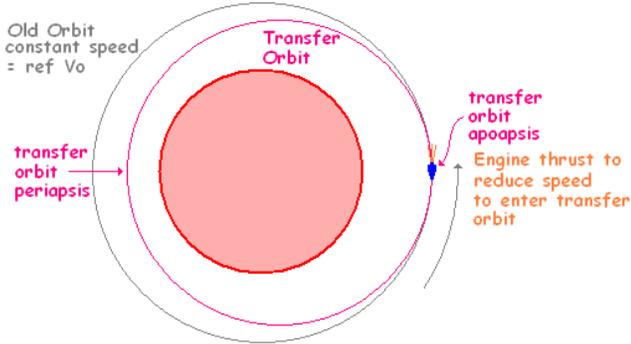


### 1.5.3.2 Decreasing the Altitude

- 1) Set both the target and reference objects to the planet you are orbiting.
- 2) Orient the spacecraft opposite the direction of the orbit (green vector should be 180° from the red vector).  
Press F3 for a prograde orbit, F2 for a retrograde orbit.
- 3) Set engine thrust to produce a 5 to 10 m/s<sup>2</sup> acceleration.
- 4) GUIDO will give you data on acceleration and duration of engine thrust.  
If GUIDO data is not available, continually press 'o' to project your new orbit. Once the periapsis projection equals the desired orbital altitude, stop engines. Reduce thrust as desired periapsis projection is approached to avoid overshooting.
- 5) Wait until spacecraft descends to periapsis.
- 6) Just before periapsis, set engine thrust to *reduce* Vtan to match ref Vo. This will circularize your orbit.

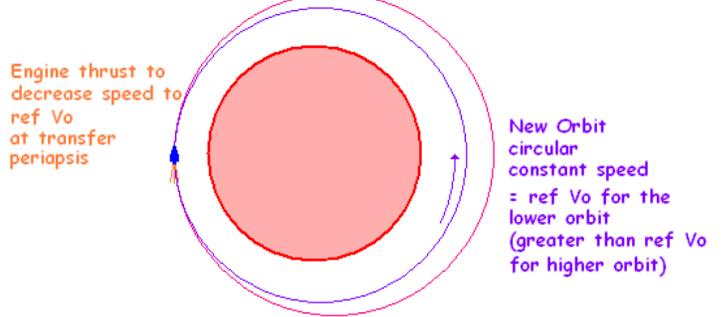
#### Step 1:

##### Decrease Altitude



#### Step 2:

##### Circularize Orbit



### 1.5.3.3 Adjusting Velocity in Space

In space there is no friction. This is nice, because once the engines have imparted a speed to the spacecraft, we can turn the engines off and the spacecraft keeps moving. It is not so nice when it comes time to change the velocity. We cannot apply the brakes to slow down (they work with friction) or rotate the wheels to turn the spacecraft (that involves friction as well).

**Speeding Up:** - point the spacecraft in the direction that you are going (F7; **pro Vtrg**) and apply engine thrust  
- if the spacecraft has any other orientation, it will change direction as well as speed

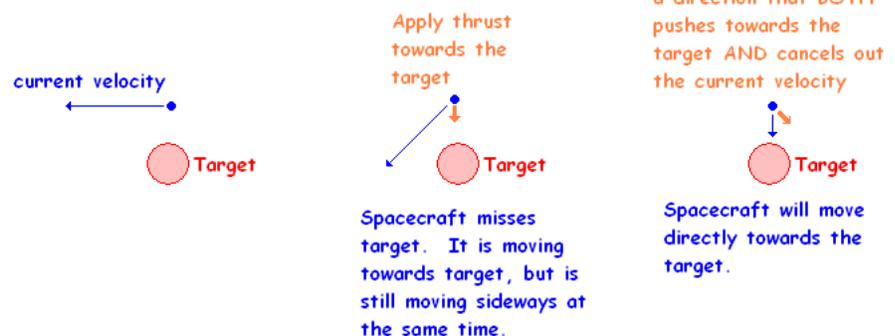
**Slowing Down:** - point the spacecraft opposite to the direction you are moving (F8; **ret Vtrg**) and apply engine thrust  
- if the spacecraft has any other orientation, it will change direction as well as speed

#### Changing Direction:

This is more complex, because you must simultaneously reduce your speed in the direction you are going and increase your speed in the direction that you want to go.

For example:

**You want to move towards the planet, but are moving sideways relative to it.**



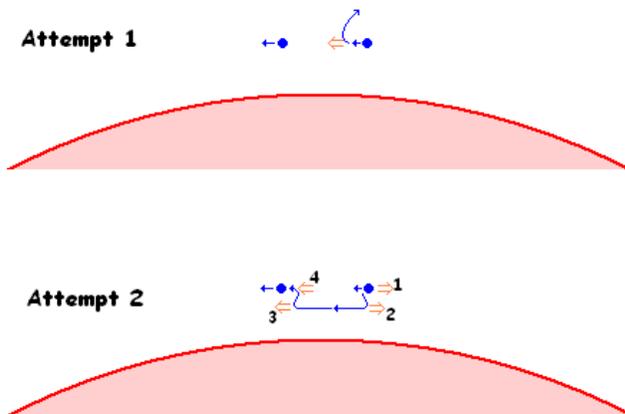
### 1.5.3.4 Adjusting Your Speed While In Orbit

This is a very complex problem, because any change in speed will also affect the altitude, which will then further affect the speed. As an example, consider a spacecraft which must join up with an orbiting space station at the same altitude. The spacecraft is several kilometres behind the space station, moving at the same speed (since it is at the same altitude).

**Attempt 1:** If the spacecraft uses engine thrust to push towards the space station, it will move faster towards the space station for a brief time, but since it is moving faster than ref  $V_0$  it will increase in altitude and as it does this, it will slow down and get farther from the space station. The only way to avoid this would be to continuously push towards the earth with the engine to hold it at the proper altitude. This would use a lot of fuel.

The other big disadvantage with this method is that the spacecraft would need to slow down when it reached the space station. This would result in engine exhaust being aimed towards the space station, probably damaging it.

**Attempt 2:** The spacecraft pushes away from the space station to slow down<sup>1</sup>. If is far from the station at this point, so there is not danger from the exhaust. This will cause the spacecraft to slow down and move into a lower, faster orbit. Once the new orbit is circularized<sup>2</sup>, the spacecraft will catch up with the space station. When it is near enough, it thrusts forward to speed up<sup>3</sup>, which will cause it to move up to the space station's altitude. Once the orbit is re-circularized<sup>4</sup>, the spacecraft will be in a stable orbit right beside the space station and at the same speed. All the engine burns near the space station will be aimed away from the station.



When you are very close to you target in orbit (the space station or AYSE drive unit), you can push towards, away, or to one side of the other with the vernier thrusters. The changes in speed are so small that the changes in altitude are easily compensated for.

### 1.5.4 Orbital Rendezvous

- 1) Choose Target and Reference as the current planet you are orbiting
- 2) **Stay set to choose CENTRE at all times to avoid inadvertent redirecting of the spacecraft.**

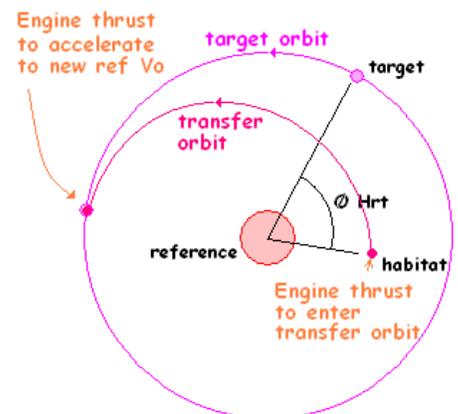
#### 1.5.4.1 Low Energy Method (GUIDO provides angle timing and thrust data for transfer orbit burn)

- 1) Set NAVmode to ccw prog or ccw retro depending on orbital direction.
- 2) Initiate required thrust at required  $\Theta$  Hrt angle for the required duration.

The correct thrust ensures that the apoapsis of the spacecraft is the same as the orbital altitude of the target. The correct angle at engine burn ( $\Theta$  Hrt) ensures that the spacecraft and target are in the same place at the apoapsis. Thrust setting, duration, and  $\Theta$  Hrt are provided by the TRANSORB software.

The engine burn must be made while behind the target since for much of the transfer orbit the spacecraft will be travelling much faster than the target.

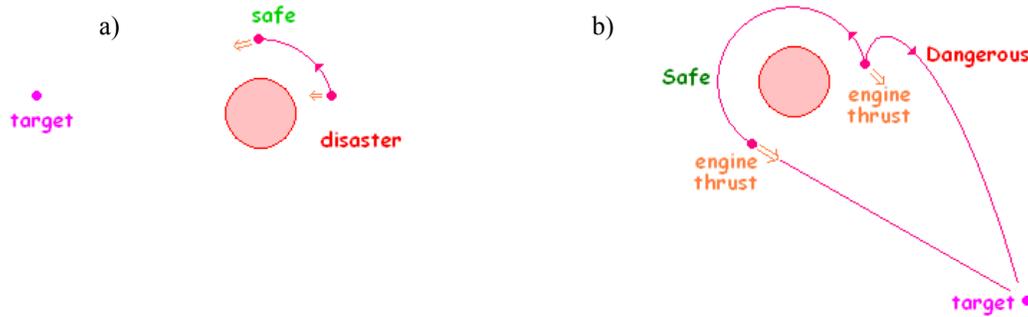
- 3) When the spacecraft and target rendezvous at apoapsis, apply thrust to achieve the correct ref  $V_0$ .
- 4) Use engines to reduce ACC to zero (spacecraft is stationary with target).
- 5) Use vernier thrusters or fractional engine settings to join up with target if needed. (see 1.5.4.2 note 8 below for instructions on how to do this).



### 1.5.4.2 High Energy Method (Direct burn to rendezvous)

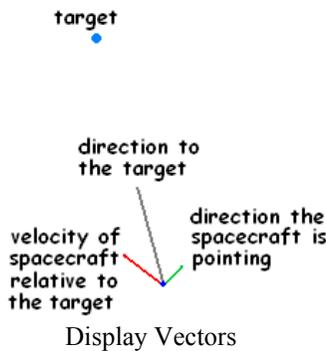
In a high-energy rendezvous, the engines are used continuously. They are used to push towards the target for the first half of the manoeuvre (pushing the spacecraft faster with time) until the half-way point. They are then used to push away from the target to continuously slow the spacecraft down to a stop at the target.

- 1) Select destination as target and reference.
- 2) a) **Wait until the destination is well over the horizon of the planet (grey vector should not point towards other objects).**  
 b) **If the target is behind the spacecraft relative to its orbit around the reference planet, wait for one half orbit so that the spacecraft is moving toward the target as it orbits the reference. This is important, because if you try to reverse direction while in orbit, your orbit may decay and the spacecraft may crash before you have a chance to build up speed in the reverse direction.**



- 3) Select **app targ** orientation.
- 4) Initiate a  $20 \text{ m/s}^2$  thrust until **ACC** approaches  $20 \text{ m/s}^2$   
 If the red arrow is off to one side of the grey target vector, adjust the orientation of the spacecraft to compensate (see note 8 below) (select NAVmode **manual** to do this).
- 5) Once ACC reaches  $20 \text{ m/s}^2$  (higher if the target is very distant) select NAVmode **dep Ref**.
- 6) Adjust thrust so that engine acceleration matches **ACC**
- 7) Select **manual** orientation.
- 8) Adjust thrust vector to keep target vector (grey) and target velocity vector (red) in line with each other. Since both the spacecraft and target are orbiting around a planet, constant adjustments to the thrust vector (green) will be needed.

This is what you want to see.



- a) The spacecraft is moving at the correct speed, but is moving to the left of the target. The pilot is applying engine thrust and aiming the spacecraft  $90^\circ$  to the right of the target. This will cause the velocity of the spacecraft swing towards the target (the red vector will swing towards the grey one). The speed will not change.
- b) The spacecraft is moving too quickly (ACC seems too large) and to the right of the target. The pilot is applying engine thrust and aiming the spacecraft away and to the left of the target. This will both slow the spacecraft relative to the target and swing the red vector to the left.
- c) The spacecraft is moving too slowly and to the right of the target. The pilot is applying engine thrust and aiming the spacecraft towards and to the left of the target. This will speed up the spacecraft and swing the red vector towards the grey one.
- d) This is what we want to see. The spacecraft is moving directly towards the target (red and grey vectors are superimposed). The thrust vector (green) is aimed away from the target as the spacecraft is applying thrust away from the target to continuously slow the spacecraft to a stop at the target.

Always return NAVmode to **dep ref** when the spacecraft velocity has been corrected.

- 9) When spacecraft is within a few hundred metres of the target, adjust thrust to reduce ACC to zero: set engine acceleration to exceed ACC until ACC drops to zero.
- 10) Use vernier thrusters or very low thrust engine pulses to join up with the target if needed (see 1.5.8).

## 1.5.5 Departure from Orbit to another planet

### 1.5.5.1 Low Energy Method

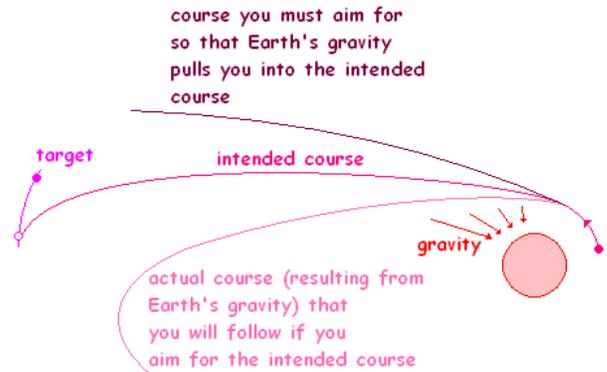
A) Transfer orbits between a planet and one of its moons works the same as a low energy rendezvous (1.5.4.1)

B) For low energy transfer orbits between planets, GUIDO must supply transfer orbit burn data.

**Orbit projection is not valid at any significant distance from the reference object.**

TRANSORB software only will provide a first approximation of the burn duration and  $\Theta$  Hrt. This is because TRANSORB only considers the effect of the gravity of the object at the centre of the orbit - in the case of the transfer orbits between planets, this is the sun. However, the gravity of the departure planet and destination planet will affect the path of the spacecraft. Thus, GUIDO will have to run a series of simulations on ORBIT5Sm to refine the parameters for the transfer orbit.

The target also is moving in its orbit. Since the transfer orbit takes a considerable length of time, it must be aimed at where the target will be at the apoapsis of the transfer orbit, not where the target is at the time the spacecraft enters the transfer orbit.



### 1.5.5.2 High Energy Method

1) Select destination as the **target** and current planet as **reference**.

2) a) **Wait until the destination is well over the horizon of the planet (grey vector should no point towards any other object).**

b) **If the target is behind the spacecraft relative to its orbit around the reference planet, wait for one half orbit so that the spacecraft is moving toward the target as it orbits the reference. This is important, because if you try to reverse direction while in orbit, your orbit may decay and the spacecraft may crash before you have a chance to build up speed in the reverse direction.**

3) Select NAVmode **App targ**.

4) Set engine thrust to achieve  $20 \text{ m/s}^2$  acceleration.

5) Once escape velocity has been reached, select NAVmode **manual**.

6) Set engine thrust to achieve the acceleration specified in the mission profile (usually 50% to 90% engine thrust).

7) Orient spacecraft so that the green orientation vector is on the other side of the grey target vector from the red velocity vector.

Watch to see that the velocity vector moves towards the target vector.

(See 1.5.4.2 note 8)

8) When velocity vector is superimposed on the target vector, select NAVmode **App targ**.

9) Watch that the velocity and target vectors remain superimposed. If the vectors become misaligned set NAVmode manual and go to step 8.

### 1.5.5.3 Rate Control

High-energy transfer orbits involve continuous engine thrust towards the target for half the orbit and continuous engine thrust away from the target to slow down for the other half of the orbit. These orbits use a lot of fuel but are orders-of-magnitude faster.

1) Monitor ACC regularly. **ACC must NEVER exceed maximum engine acceleration.**

If ACC exceeds maximum engine acceleration, there are a few corrective options.

1) Use NAVmode manual to alter the direction of the spacecraft so that it misses the target.

Once the correct direction is achieved, select NAVmode **ret Vtarg**.

Use maximum safe engine thrust to reduce speed.

Once you are past the target and speed has been reduced to a manageable level, plot a new approach path to the target.

2) If you have fuel to spare, dump fuel to lighten the spacecraft and increase maximum engine acceleration.

2) When ACC reaches the specified level (no more than 90% maximum engine acceleration):

a) Stop engine (BckSp key)

b) Select the target as the reference object

c) Select NAVmode **dep Ref**

d) If specified in mission profile, coast until ACC specified for engine restart is reached.

3) Set engine thrust to match engine acceleration to ACC.

4) Monitor ACC periodically to ensure that it is stable.

Adjust engine thrust to re-establish specified ACC as needed.

5) Watch that the velocity and target vectors remain superimposed. If the vectors become misaligned set NAVmode manual and go to step 8 of 1.5.5.2 to re-establish correct course. Reset NAVmode to dep Ref.

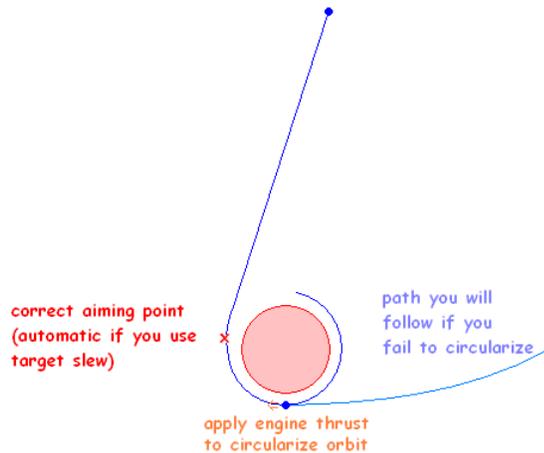
### 1.5.6 Orbital Insertion from Approach (within a million kilometers of target surface, or so)

- 1) Press “v” to display target approach velocity vector on the main display.
- 2) Select target and reference as the destination.
- 3) Press F9 or F10 to slew the target vector to the left or right of the target.
- 4) Select NAVmode manual to adjust the velocity vector line up with target vector.  
Select NAVmode ret  $V_{\text{target}}$ .  
Repeat step 4 as needed until inserted into orbit opposite direction to stabilize the approach velocity vector.
- 5) Use orbit projection (“o”) to check velocities, especially if performing a tangential approach.  
Press “p” to display tangential and centripetal speeds relative to target object.
- 6) When within 5 planetary radii, turn off slew target NAVmode. Select NAVmode **ret  $V_{\text{trg}}$** .
- 7) Your goal is adjust thrust to slow the  $V_{\text{hab-ref}}$  and  $V_{\text{tan}}$  to the **ref  $V_0$**  velocity of the intended orbital altitude and the  $V_{\text{cen}}$  to zero before you reach your desired periapsis.

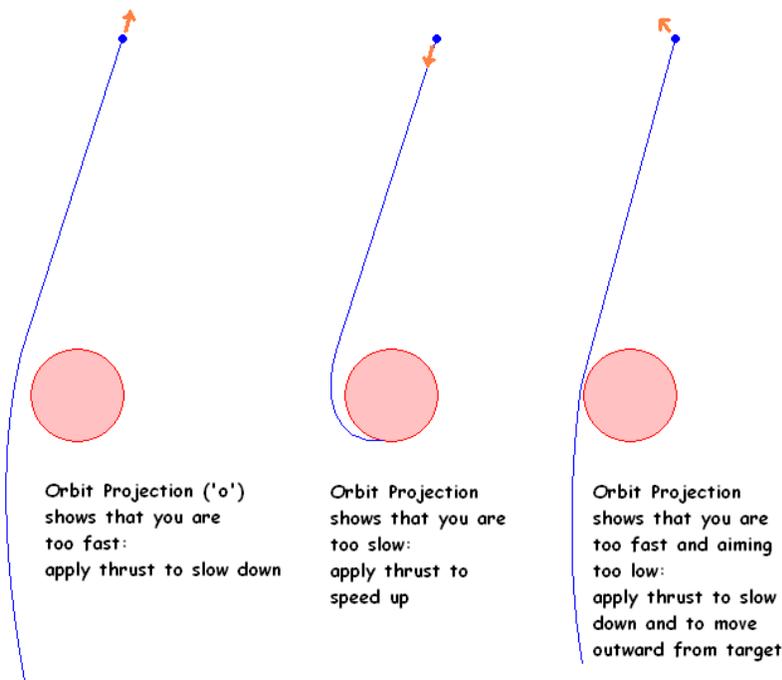
If projected periapsis is correct, but speed is too great (more than can be adjusted for at periapsis), use engine thrust to reduce speed. When speed has been reduced, set NAVmode to dep Ref and use engine thrust to restore projected periapsis to desired altitude.

If aerobraking is part of the plan for reduction of speed, GUIDO must run simulations to determine correct approach profile.

- 8) When orbit projection shows desired periapsis and speed is within limits, shut off engines and coast to periapsis.  
Use engine thrust periodically to counteract the effect of gravitational acceleration as you approach the planet.
- 9) When near periapsis, use engine thrust to reduce speed to ref  $V_0$ , thus circularizing the orbit.



### Some Potential Problems and the Corrective Actions

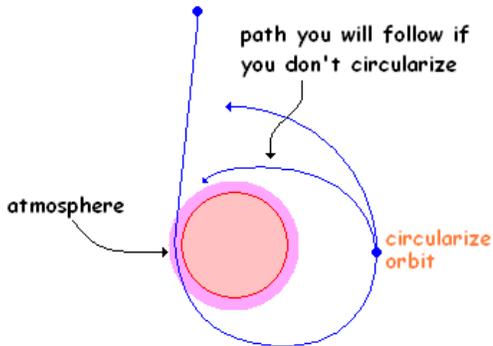


## Aerobraking

Aerobraking is a technique to reduce speed at the destination with minimal expenditure of fuel. This is useful for very fast transfer orbits as the fuel load and total mass of the spacecraft can be minimized. It also is useful for very long voyages where the spacecraft may not have enough fuel for the return trip if it is used to slow down at the destination.

Aerobraking only works where the destination planet (or one nearby) has a thick atmosphere.

This technique is very dangerous and must be researched with the simulator to work out the exact mission profile. Typically, there is a window of only a few tens of kilometres above the surface of the destination planet that the spacecraft must pass through in order for the manoeuvre to be successful. If you are too shallow (not far enough into the atmosphere) at the closest approach, your speed will not be reduced enough and you will not be captured into an orbit about the planet. If you are too deep (too far into the atmosphere), you will slow down too much and may crash. In a thick atmosphere, the engines may not have enough engine thrust to push your way up back into orbit.



In this circularization manoeuvre, you should have to increase the  $V_{tan}$  to match  $ref V_0$ , unless your braking manoeuvre was too shallow. In the latter case, you will have too large a speed and will have to use engine thrust in the opposite direction to decrease speed.

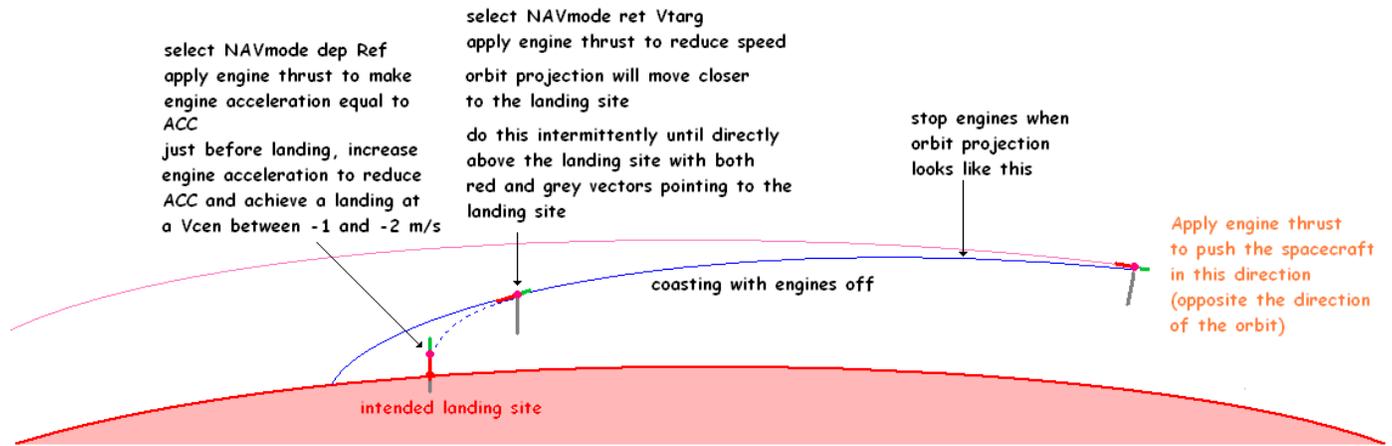
## 1.5.7 Landing Procedure

**If Docked to the AYSE drive unit, you must undock from the AYSE drive while in a stable orbit. The AYSE drive unit cannot land without crashing. It must be left in orbit before landing.**

- 1) Select the destination as target and reference.
- 2) Press **v** key to activate the approach velocity vector if not done already.
- 3) Select NAVmode **ccw retro** if in a counter clockwise orbit, (**ccw prog** if you are in a clockwise orbit).
  - a) Consult GUIDO for appropriate engine acceleration and lead angle to your landing site.
  - b) If GUIDO assistance is not available, use orbit projection to plan your landing.
- 4) Apply engine thrust until orbit projection intersects the surface just past the target.

On a planet with a substantial atmosphere, the intersection should be farther past the target.
- 5) Coast until the spacecraft is nearing the target and ACC is approaching 50% of the planet's gravity.
- 6) Select NAVmode **ret V<sub>targ</sub>**.
- 7) Apply engine thrust to hold a constant ACC of not more than 50% larger than the planet's gravity.
- 8) When  $V_{tan}$  is zero (or very close), select NAVmode **dept Ref**.

**Do not land in any NAVmode except manual or dept Ref.**
- 9) Increase engine thrust to lower ACC to 10% to 20% above local gravity.
- 10) **If ACC exceeds maximum engine acceleration:**
  - @ Low Altitude: maintain maximum thrust and brace for hard landing
  - @ High Altitude: Initiate Landing Abort Procedure
    - set maximum available engine thrust which may be more than 100% (consult engineer).
    - set NAVmode manual and rotate to about 45° above the horizon
    - maintain engine thrust until orbit projection shows that you will miss the planet's surface
- 11) If the approach velocity vector starts to point away from the centre of the target, rotate the hab slightly in the opposite direction to correct it then re-adjust the orientation to stabilize the approach velocity vector.
- 12) At 0.001 km altitude, stop adjusting engine setting.
  - Do not land at an engine setting larger than 2 m/s<sup>2</sup> above local gravity**
  - Do not land at a speed greater than 2 m/s**
  - Do not land at a frame rate greater than 0.25**



If landing in an atmosphere, delay applying engine thrust until atmospheric drag has fallen below 20 m/s<sup>2</sup>. Engine damage may occur with heat from atmospheric ionization.

## 1.5.8 Docking and Undocking

### 1.5.8.1 Docking

- 1) Establish a close orbit with which to be object docked. (see 1.5.4)
- 2) Use low thrust engine pulses to line up the hab with the docking hatch.  
For the AYSE drive unit, there is no specific docking hatch.
- 2) Orient the hab so that its docking hatch is parallel to the axis of the docking hatch of the space craft with which to be docked.  
The habitat docking hatch is centered between the engine pods.  
**The habitat must be in the docking orientation (Depart Ref) in order to dock.**
- 3) Use vernier engines to move the hab so that it is lined up with the docking hatch.  
The vernier engines fire a brief burst **once each time the key is pressed**. They **do not** stay on.  
Opposite vernier engines must be used to cancel out the velocity once the desired position is attained.  
Slow down gradually ahead of time to avoid over-shooting your desired position
- 4) Once in position, use vernier thrusters to push back towards the docking hatch.
  - A) For ISS docking, **make contact at less than 2 m/s and at a frame rate of 0.25.**
  - B) For AYSE drive unit docking, make contact at 10 m/s and continue inward to a distance of 300 m from the surface (-0.300 km distance). Come to a stop at that point.

Alternatively, at a distance of less than 1000 km from the AYSE drive unit, set the hab in a stable orbit (see notes 13 and 14 in 1.5.2). Request engineer initiate AYSE AUTODOCKING.

When engineer verifies that the hab is in position, AYSE drive and HAB can connected (see section 1.6).

### 1.5.8.2 Undocking

- 1) Apply 3-5 bursts from forward vernier thrusters to initiate a departure.
- 2) When at a distance of at least 1 km, use verniers to increase velocity relative to the docked object.
- 3) Wait until a separation of 20 km from docked object has been achieved.
- 4) Select NAVmode ccw prog or ccw retro as appropriate.
- 5) Use engine thrust to stabilize the orbit or achieve a different orbit.  
When altering the orbit, make certain that the new orbital velocity will not result in closure with the docked object.

### 1.5.8.3 Undocking and Docking with Longhouse Module

- 1) The Longhouse module can be detached while the habitat spacecraft is landed on a planet or moon. This is done from the engineering console (section 1.6)
- 2) The Longhouse module can be reattached from the engineering console. The habitat must be landed on the same planet as the module and within 80 metres.

## 1.6 Engineering/Power Distribution System (ORBIT5SE)

### 1.6.1 Theory

The Habitat and AYSE power distribution system resembles the same sort of electrical circuits that we learn about in grade 9 science classes. The system consists of a number of sources (reactor generators, batteries, and fuel cell), loads (engines, radiation shields, etc.), conductors (bus bars and wires), and switches. The system is a parallel circuit system, just like a house, so that each load draws electrical current independently of any of the others. The various sources also are in parallel so that each contributes part of the current going through the circuit.

- Energy (E):** The ability to do work. Measured in Joules (J)
- Charge (Q):** Particles such as electrons. Measured in Coulombs (C).  $1C = 6.24 \times 10^{18} e^-$
- Voltage (V):** How much electrical energy added to or removed from the charges. Measured in Volts (V);  $1V = 1J/C$ .
- Current (I):** How many charges pass through a part of the circuit per second. Measured in Amps (A);  $1A = 1C/s$ .
- Resistance (R):** Voltage needed to create a current through a part of the circuit. Measured in ohms ( $\Omega$ );  $1\Omega = 1V/C$ .

The charges can be views as energy carriers, moving electrical potential energy from one part of the circuit to another.

The current passing through a circuit depends on the resistance of the circuit according to Ohm's Law:

$$R = V/I \text{ which can be restated as } I = V/R$$

(the lower the resistance or higher the voltage, the greater the current)

In most circuits, the conductors and switches have negligible resistance. All of the resistance comes from the loads and the sources. The source resistance is hard to measure as most of its effects are internal to the source itself. Most of the time, all that we notice a drop in voltage coming out of the source.

The energy added by the source is removed by the circuit before each charge returns to the source. It can be converted to different forms such as heat, light, motion, sound. The type of load determines what sort of transformation takes place. If the conductors carry out this transformation (such as in a short circuit), all of the energy is converted to heat.

**Power (P):** the rate at which energy is used (J/s or Watts (W)).

In an electrical circuit, power can be calculated as:

$$P = VI \text{ more energy per charge, more charges per second, or both will increase the rate that energy is used.}$$

Generally, the voltage of a circuit is fixed by the source. So to increase the power of a load we much increase the current. The only way to increase current at a constant voltage is to decrease resistance. So, high power loads (main engines, for example) usually have low resistance.

#### 1.6.1.1 Series Circuits

All the charges must pass through all parts of the circuit. If there are any breaks in the circuit, the current stops everywhere in the circuit. Since charges cannot bunch up in any one part of the circuit (they repel each other, after all), the current must be the same in all parts of the circuit.

$$I_c = I_1 = I_2$$

The total resistance of the circuit determines how much current goes through the circuit.

$$I_c = V_s/R_T$$

$$R_T = R_1 + R_2$$

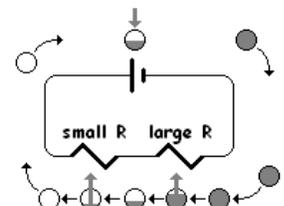
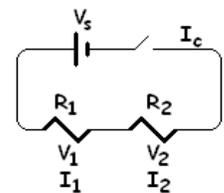
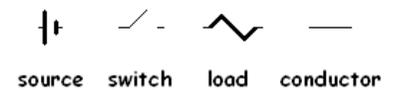
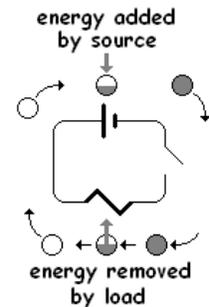
Each load takes some of the electrical potential energy (voltage) from each charge. The total energy removed by all the loads equals the energy added by the source.

$$V_1 + V_2 = V_s$$

The voltage of each load (what share of the total energy per charge) is determined by the resistance of that load. The greater the resistance compared to the total resistance, the greater the voltage (the bigger its share of the electrical potential energy).

$$V_1 = V_s(R_1/R_T)$$

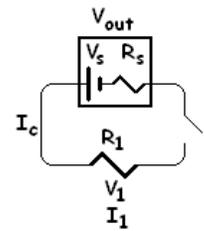
#### Energy Changes in a Simple Circuit



### 1.6.1.2 Practical Application

Why is this important for us, if our electrical system is a parallel rather than series circuit?

The reason is that all sources have their own internal resistance and the source is in series with its loads. Because of this, some of the energy added to each charge in the source actually is converted into heat inside the source.



The voltage that actually comes out of the source to the rest of the circuit ( $V_{out}$ ) is less than  $V_s$ .

$$V_{out} = V_s - V_{in}$$

Even in a simple circuit with one load,  $R_T = R_s + R_1$

$$V_{in} = V_s(R_s/R_T)$$

The lower the resistance of the load ( $R_1$ ), the larger is ( $R_s/R_1$ ) and the larger is  $V_{in}$ .

So, if a high resistance source is used to power a very low resistance load, the  $V_{out}$  will be much reduced and the rate at which the source heats up ( $P_{heat} = I_c \times V_{in}$ ) will be greatly increased. The loads will be under powered and the source (battery or generator) will overheat and be destroyed.

So, we cannot power the main engines with our small, high internal resistance fuel cell or batteries without melting the source. Chemical batteries increase in internal resistance as they use up their supply of chemicals. This is why battery voltage drops as the battery ages. However, if you measure the voltage of even a old battery without turning on the circuit, the voltage looks fine. This is because the resistance of the circuit is effectively infinite with the switch open, so  $V_{in}$  is close to zero.

### 1.6.1.2 Parallel Circuits

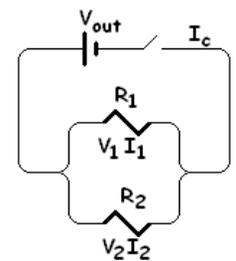
In a parallel circuit, each load has its own path to and from the source that does not pass through any other load. Since each charge passes through only one load, each load has exactly the same voltage as  $V_{out}$ . Each load takes all of the electrical potential energy out of each charge that passes through it because there are no other loads on that path.

$$V_1 = V_2 = V_{out}$$

The current coming out of the source must equal the sum of the current going through each load.

$$I_c = I_1 + I_2$$

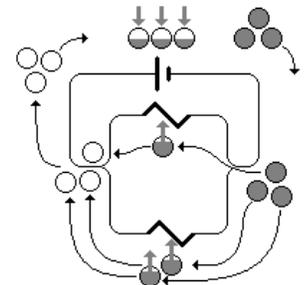
$$I_1 = V_{out}/R_1 \quad \text{neither } V_1 \text{ nor } I_1 \text{ depend directly on } R_T$$



Since the total current increases as more loads are added (or are turned on), the total resistance must decrease:

$$1/R_T = (1/R_1) + (1/R_2)$$

The real danger is that as more loads are turned on,  $R_s$  becomes larger compared to  $R_T$  and the source gets hotter and  $V_{out}$  gets lower! Eventually, either  $V_{out}$  gets too low for the loads to work properly or the source is destroyed.



The top load has a higher resistance so it has a lower current.

### 1.6.1.3 Short Circuits

If a direct connection is made between the positive and negative terminals of the source without a load in between, almost all the resistance of the circuit will be inside the source. All the voltage will go into heating up the source itself (and the conductor to a certain extent). Most short circuits don't drop the circuit resistance to zero, but make it much lower than it should be. Even so, they are often enough to cause the source to overheat very rapidly.

### 1.6.1.4 Circuit Buses

Buses are large conductors designed to carry very large currents with very low resistance. They are constructed such that multiple loads can be clipped onto them in a parallel arrangement.

### 1.6.1.5 Multiple Sources

In a system such as our spacecraft, the circuit has a number of separate buses each of which may have more than one source in parallel to each other (a battery and a fuel cell for example). The buses can be cross-connected to each other to increase the potential number of parallel sources. In a situation where you have more than one source at the same voltage contributing to the current in the circuit, the different sources usually do not contribute equally to the current. The greater the internal resistance of a source, the lower its contribution to the total current of the circuit.

### 1.6.1.6 Types of Current

Current can be direct (DC) or alternating (AC). In direct current, the charges move in one direction around the circuit. It is much simpler to model mathematically. In alternating current, the charges vibrate back-and-forth and don't travel very far in either direction.

One advantage of alternating current is that its voltage can be altered by a transformer. Power is not changed by a transformer.

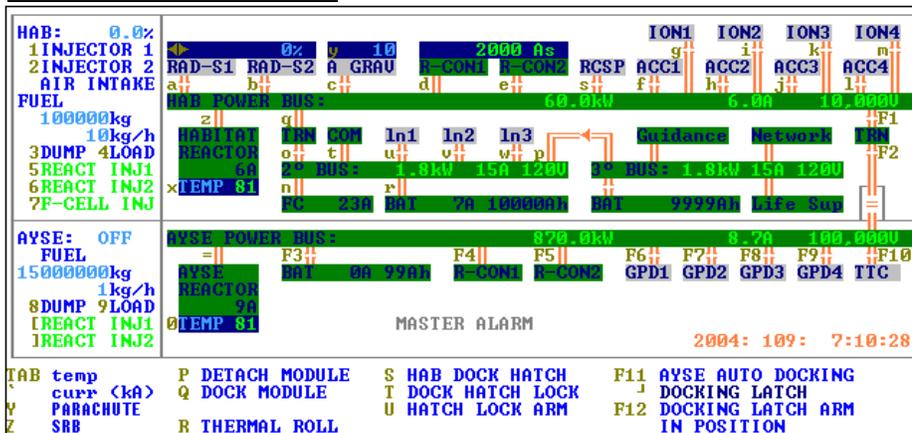
Since:  $P = V \times I$

If V is increased, I is decreased and visa versa.

Alternating current can be converted to direct current using a rectifier.

Direct current can be converted to alternating current using an inverter.

### 1.6.2 Orbit5SE user interface



The power distribution circuit control interface is used by the astronaut engineer. Only the hot side of the circuits are shown. The neutral (ground) ground bus bars are not shown since there no switches to control.

This system allows the astronaut-engineer to control:

- engine functions
- electrical power generators (reactors, fuel cells, batteries),
- fuel distribution systems,
- electrical power distribution
- docking

### 1.6.3 Electrical Power Distribution

The habitat space craft has three main power buses (large, high-voltage, high-current conductors). Each bus has a set of devices drawing power from it. The buses have different voltages, but the engineer can send electrical power from one bus to another through transformers to adjust the voltages. Voltages outside the normal range are indicated by the colour of the data readout for each bus.

#### 1.6.3.1 HAB Power Bus

This is a 10,000 V DC bus which supplies power to the habitat engines, vernier thruster compressor, antigravity field generator, magnetic radiation shield field generators, and back-up capacitors for the fusion reactor control systems.

The primary power supply for the HAB bus is the fusion reactor which is connected directly to the bus.

The HAB power bus can draw power from the secondary bus through a transformer/rectifier/inverter (TRN). The HAB bus also can draw power from the AYSE Power bus through another TRN when the HAB is docked to the AYSE drive unit.

#### 1.6.3.2 Secondary Power Bus

This is a 120 V AC bus. It supplies power to the TTC and radio communications systems and the three electrical power circuits within the habitat.

The primary power supplies for the secondary bus are a fuel cell and a rechargeable battery. The bus also can receive power from the HAB power bus through the TRN.

### 1.6.3.3 Tertiary Power Bus

This also is a 120 V AC bus. It supplies power to the computer networking system, navigation computers, and life support systems.

The primary power supply for the tertiary bus is the secondary power bus. There is a back-up battery that connects automatically if the switch between the secondary and tertiary buses is opened or if the secondary bus loses power. The tertiary bus cannot supply power to the secondary bus through its battery.

### 1.6.3.4 AYSE Power Bus

This is a 100,000 V DC bus. It supplies all systems on the AYSE drive.

The AYSE drive can draw power from the AYSE fusion reactor and from a back-up battery. The battery only has the capacity to run the AYSE reactor plasma containment system, not the AYSE engines. The AYSE bus also can draw power from the HAB bus when the HAB is docked to the AYSE drive to supplement the AYSE reactor output. The HAB reactor only is capable, on its own, of running one of the four AYSE engines at a very reduced thrust level.

### 1.6.3.5 TRN Power Transfer Control

In order to shunt power from one bus to another, the switch on either side of the TRN must be closed.

Before transferring power the potential load on the sources of each bus must be assessed. You must determine if there are any high current loads (engines, for example) switched on that might draw too much current from a high resistance sources (such as the fuel cell on the secondary bus).

Example: The secondary and HAB buses are cross connected.

a) If the engines, anti-gravity field generators, or magnetic shield field generators are switched on and the HAB reactor is switched off, the loads will draw so much current from the fuel cell that it will be destroyed in seconds.

b) If the HAB reactor is switched on, its resistance is so low compared to that of the fuel cell that almost all of the current will be drawn from the reactor and the fuel cell will remain intact. If the reactor were to malfunction and switch off, all of the current would be drawn from the fuel cell and it would be destroyed faster than the engineer could react.

Therefore, if buses are to be cross-connected, it is prudent to switch off all of the high resistance sources on the lower-power bus.

### Advantages of Cross-connecting Buses

1) Cross-connecting HAB and secondary buses: the fuel cell is much less efficient than the HAB reactor. Much less fuel is used if the HAB reactor is used to power the secondary bus.

2) Cross-connecting HAB and AYSE buses: the HAB reactor does not have sufficient capacity to run the magnetic shield field generators or the anti-gravity field generator at more than 33% of maximum capacity (16% if they are both running at the same time). The AYSE reactor can power both at 100% while powering the AYSE engine systems are near 100% at the same time. The AYSE drive unit also has a much larger fuel supply. If an emergency HAB/AYSE separation becomes necessary, it is good to have maintained a full fuel supply on the HAB.

## 1.6.4 Electrical Generators

Current and temperature must be monitored for all functioning sources. Press **TAB** to display the temperature of the batteries and fuel cell. Temperature ranges also are displayed by the colour of the readout for that source.

### 1.6.4.1 HAB Fusion Reactor

The HAB fusion reactor is a fusion-powered, magnetohydrodynamic (MHD) generator. It has sufficient capacity to run most of the electrically powered systems at the same time, with the following exceptions:

- a) the reactor can power the engines to 100%, but can only sustain engine output of 90% without overheating.
- b) the reactor can power the magnetic radiation shield field generators to 33% of their maximum output.
- c) the reactor can sustain 33% radiation shielding *or* 90% engine thrust, *not both*.
- d) the reactor can supply sustain power to the anti-gravity field generator at a level sufficient to counteract the HAB engines at maximum thrust, but cannot sustain sufficient power to counteract the AYSE drive engines and run the magnetic shield field generators.

Monitor reactor temperature periodically to ensure that it is running within limits. The reactor can take a long time to overheat even when pushed past its maximum setting, so *both* the rate of change in temperature *and* current temperature must be monitored.

The Habitat spacecraft can carry sufficient fuel to power the reactor for full HAB engine thrust for a period of about 8 hours.

#### **1.6.4.1.1 HAB Reactor Cold Start-up Procedure**

Important considerations:

- reactor must be at 80% maximum rated temperature before it will function.
- a cold reactor must be brought up to 80% temp using the reactor heater before reactor fuel pumps are turned on.
- if reactor temperature is above 30%, a plasma confinement field generator (R-CON) must be running or reactor will fail.
- fuel cell has the capacity to power *either* an R-CON *or* the reactor heater, *not both*.
- fuel cell stores charge in the R-CON capacitor (R-CON CAP) which powers R-CON while fuel cell powers reactor heater.
- the cold start-up procedure can take as long as 20 minutes.

1) Open all switches on the HAB Power Bus.

Open switch **p**.

Open switches **t**, **u**, **v**, and **w** on the secondary bus.

2) Close switch **r** to power secondary bus from battery.

3) Close switch **7** to start fuel cell supply pumps.

4) Open switch **r** to isolate the secondary bus battery.

5) Close switches **q** and **o** to power the HAB power bus.

If the R-CON CAP has a charge of at least 1500 amp seconds, proceed to step 10.

6) Close switch **e** or **d**.

7) Monitor fuel cell temperature (press **TAB** to display temperatures) while reactor confinement capacitor charges.

If fuel cell overheats, open switch **q** and let it cool down (fuel cell failure will occur when temp exceeds 110% rated max).

8) When R-CON CAP has a charge of at least 1500 amp seconds, open *both* switches **e** and **d**.

9) Allow fuel cell to cool down to 50% max temp (the lower the better).

10) Verify that switch **z** and all HAB power bus load switches are *open*.

11) Close both switches **q** and **o**.

12) Close switch **x** to start reactor heater

13) Monitor HAB reactor temperature, fuel cell temperature, and R-CON CAP charge

At 30% rated max., reactor confinement will start and reactor confinement capacitor (RC cap) will start to discharge.

If R-CON cap charge gets dangerously low, open switch **x** and close switch **e** or **d** to recharge capacitor.

If fuel cell temp climbs to 110%, close switch **n** and allow fuel cell to cool.

- do not leave fuel cell switch (n) open for too long or R-CON CAP will discharge too far to complete the process.

If R-CON loses power while reactor temperature is above 30%, the reactor will be destroyed.

14) When reactor temp goes over 80% (read-out turns green):

a) start reactor fuel pumps (close switches **5** and **6**)

b) close switch **z** to send electrical power from the reactor to the HAB power bus

15) Close switches **d** and **e**.

16) Open switch **n** to isolate the fuel cell and allow it to cool.

#### **1.6.4.1.2 Reactor Shutdown**

If the AYSE power bus is cross-connected to the HAB power bus and is supplying power to the HAB, proceed to step 4.

Otherwise, start at step 1.

1) Shut down all high-load systems drawing power from the HAB power bus except R-CON (open switches **a** through **m** and **s** except switch **d** or **e**).

2) Close switches **o** and **q**.

3) Verify that fuel cell is running and functioning properly within load and temperature limits.

4) Open switch **z**.

5) Stop the reactor fuel pumps (open switches **5** and **6**).

6) Monitor R-CON until reactor temperature falls below 30%.

#### **1.6.4.1.3 Normal Reactor Function**

1) Ensure that fuel supply is sufficient for continued reactor output. If fuel is likely to be exhausted, preparations must be made for reactor shutdown.

2) Make sure that both reactor fuel pumps are functioning. If one is off, the maximum reactor output is reduced and the internal resistance of the reactor generator is increased.

3) Monitor temperature and output current to verify that they are within safe limits.

4) Periodically monitor reactor control systems current (press **`**, also the **tilde** key). Current outside normal limits can signal an internal malfunction.

### **1.6.4.2 HAB Fuel Cell**

The fuel cell uses the same fuel as the HAB reactor, but generates power using a chemical reaction rather than nuclear fusion.

#### **Power Up:**

- 1) Ensure that switch **n** connecting the fuel cell to the secondary bus is open.
- 2) Press **7** to start the fuel pump.
- 3) Assess the loads connected to the secondary bus (including any loads on cross-connected buses). Disconnect any dangerous loads.
- 3) Close the bus switch **n**.

#### **Normal Use:**

Maximum safe current for the fuel cell is 720 amps.

Monitor current and temperature periodically.

Charging the R-CON capacitor or running the HAB reactor heater will exceed the maximum fuel cell output. Charging and heating may have to be interrupted to allow the fuel cell to cool.

#### **Power Down:**

- 1) Open bus switch **n**.
- 2) Press **7** to stop the cell's fuel pump.

### **1.6.4.3 Batteries**

All of the batteries are rechargeable nano titanate cells. They do not rely directly on the fuel supply as does the fuel cell, but must be recharged as their stored charge is exhausted, whereas the fuel cell can run continuously as long as there is fuel.

#### **Power Up:**

- 1) Assess the connected and cross-connected loads prior to connecting a battery.
- 2) Closing the switch to the power bus.

#### **Normal Use:**

Monitor current and temperature periodically.

All of the batteries have low maximum current:

secondary bus battery:	58 amps @ 120 V
tertiary bus battery:	15 amps @ 120 V
AYSE bus battery:	77 amps @ 100,000 V

Batteries cannot be used to power any of the primary loads on either the HAB or AYSE power buses.

The HAB secondary bus battery cannot be used to power either the R-CON capacitor or the reactor heater.

The tertiary bus battery cannot transfer power to the secondary bus. Transfer current from tertiary to secondary buses is blocked.

The AYSE bus battery can be used to power the AYSE R-CON systems and AYSE reactor heater.

#### **Power Down:**

- 1) Open the bus switch for the battery.

When the battery switch is open and the bus voltage is within set limits, the battery will automatically recharge.

Battery charge in amp hours is displayed on the user interface readout:	secondary bus battery:	10,000 amp hours
	tertiary bus battery:	10,000 amp hours
	AYSE bus battery:	100 amp hours

#### **1.6.4.4 Monitoring for Electrical Power Distribution Problems**

The electrical distribution system must be monitored continuously for a number of potential problems.

In order to properly assess the state of the electrical power distribution system, the current, voltage, and temperature states should be recorded for common system settings when the system is known to be operating properly. These then can be quickly compared to actual current, voltage, and temperature states at any time.

##### **1.6.4.4.1 Short Circuits**

A short circuit on an electrical bus or any of the conductors leading off of it will lower the total resistance for that bus.

The following are symptoms of a short circuit:

- 1) **The current indicated on the bus will be greater than the sum of the current for each of the loads on the bus.**

Periodically, press “~” key (also the tilde key) to display the current for each load. Add them up and compare to bus current.

- 2) Secondly, the voltage will be lower than normal and the reactor temperature will be higher than normal for the current setting on the various loads.

If a short circuit is suspected, the load on the bus must be reduced so that a visual inspection of the bus can be made to check for contact between the bus and grounded objects. Broken insulation and loose connections on connections to the bus also must be checked. Because of the way load are switches are attached, turning off different components is not likely to help find the short.

##### **1.6.4.4.2 General System Malfunctions Within a Source**

There are a number of components within the circuitry of a source that, when damaged, can increase the internal resistance of the source. The following are symptoms of such a malfunction.

- 1) The bus voltage will be lower than normal for the current systems settings.
- 2) The source temperature will be higher than normal for the source output.
- 3) The bus current will match the sum of the current on each of the loads.
- 4) Serious malfunctions may be flagged by system diagnostic software with a red background on the user interface.

Such malfunctions may have very small effects at low source output. A significant increase in source internal resistance may cause a change of only a few tens of volts at low power and not have any noticeable affect on source temperature. However, when bus current is increased, the voltage will drop drastically and source temperature may rise too rapidly to avoid serious damage to the source.

It is important to assess the voltage on the buses before any large increases in the load off the bus are implemented and to closely monitor the rate of temperature change after the increase in load.

If a malfunction is suspected, the source must be deactivated, powered down, and the safety cover removed for inspection of circuit components. This is not possible for the core components of the HAB reactor. A serious malfunction of the core HAB reactor systems necessitates a mission abort using the AYSE drive. Most components that can be serviced are swapped with spare units. Do this one at a time to determine which component is malfunctioning.

##### **1.6.4.4.3 Voltage Regulator Malfunction**

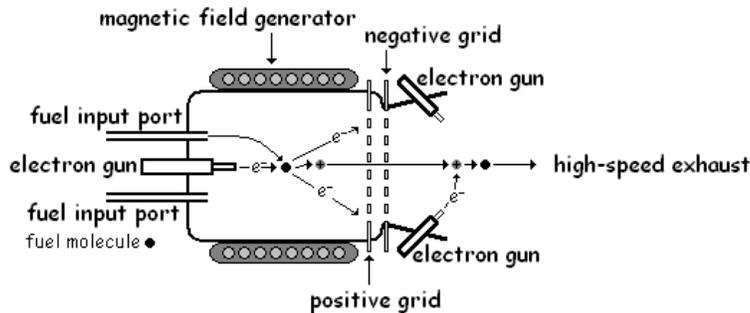
The voltage regulator on each power source maintains the correct internal voltage. Malfunctions in these components display specific symptoms:

- 1) The bus voltage may be too high or too low.
- 2) In the case of high voltage, current in other sources connected to the same bus may run in reverse.  
In the case of low voltage, other sources will be putting out anomalously high current.
- 3) The temperature of the source will be correct for its power output.
- 4) Bus current will match the sum of currents on all connected loads.

If such a malfunction is suspected, the voltage regulator circuit card for that source can be swapped with a spare card.

## 1.6.5 Habitat Systems

### 1.6.5.1 Habitat Main Engines



The main engines of the habitat space craft are ion thrusters.

Spent fuel molecules from the HAB reactor are injected into the ionization chamber. An electron gun is used to ionize the fuel molecules by knocking electrons from the molecule to make positive ions. The electrons are absorbed by a positively charged grid. The positively charged ions are accelerated by a negatively charged grid out the back of the engine. With sufficiently high voltage, very large exhaust velocities can be obtained: orders of magnitude faster than chemical rockets. This results in orders of magnitude greater thrust for the same mass of fuel. A magnetic field is used to help contain the plasma inside the ionization chamber and to produce greater acceleration of the ions. Electron guns in the exhaust nozzle re-neutralize the exhaust to prevent the spacecraft from developing a negative static charge.

Power for the electron guns, acceleration grids, and the magnetic field generator are drawn from the HAB power bus.

Thrust control is achieved by adjusting the rate of fuel input coupled with adjustments to current on the electron guns. This coupled modulation of fuel and ionizing current is controlled by a computer in response the throttle setting on the piloting software.

With a full fuel load, the four HAB main engines can produce an acceleration of approximately  $45 \text{ m/s}^2$ . This acceleration will increase as fuel is used up.

#### Normal Use

- 1) HAB reactor must be functioning and supplying power to the HAB power bus (see section 1.6.4).
- 2) Switches **e** and **f** must be closed to supply full power to the reactor plasma confinement system.
- 3) Switch **s** must be closed to power the vernier thruster compressor.
- 4) Close switches for **both** the accelerator voltage (ACC) and ionizer- electron guns - (ION) for each engine that is to be running. For full power, switches **f** through **m** must be closed.
- 5) Close switches **1** and **2** to start the reaction mass pumps. These pumps send exhaust from the MHD generators to the HAB engines to be ionized and used as reaction mass for the ion propulsion system.

### 1.6.5.2 Reaction Control System - Vernier Thrusters

The vernier thrusters use jets of high-pressure gas. The gas is taken from the HAB reactor exhaust. It is stored in a pressurized tank. Pressure is replenished by a compressor pump which draws power of the HAB power bus.

#### Normal Use

The pressure tank holds enough gas for 100 pulses of the vernier thrusters. Close switch **s** off the HAB power bus to power the pump to replenish gas pressure.

### 1.6.5.3 Anti-gravity Field Generators

The anti-gravity field generator draws power off the HAB power bus.

#### Normal Use

- 1) Close switch **c** on the HAB power bus.

The controlling computer automatically adjusts the field strength to compensate for the acceleration being experienced by the HAB crew compartments.

- 2) Close switch **y** to lower the compensation effect. Astronauts will experience higher accelerations, but the field generator will draw less current.

#### Problems with Excess Acceleration

The field generator can exceed the capacity of the HAB reactor if large accelerations are experienced. These can result from high velocity aero-braking manoeuvres. Such procedures should not be attempted without cross-connecting the HAB and AYSE power buses so that sufficient power is available.

#### **1.6.5.4 Magnetic Shield Field Generators**

These field generators produce a magnetic shield that protects the crew compartment from high-energy charged particles. The effect of this shielding can be noted on the EECOM panel in the HAB control room and on the mission control EECOM control panel.

The HAB reactor can only power these generators to 33% of their maximum output, and only when all other high load devices are shut down. For greater shielding, the AYSE power bus must be cross-connected to the HAB bus.

##### Normal Use

- 1) Close switches a and b to activate the field generators. A single generator may be used on its own.
- 2) Adjust the field strength using the ← and → keys.

##### Other Options for Radiation Shielding

- 1) Stay away from the radiation source (especially the radiation belts surrounding all of the planets with strong magnetic fields. Consult RAD software for known locations.
- 2) The HAB spacecraft has substantial mechanical shielding from electromagnetic radiation and from high-energy charged and uncharged particles. Consult EECOM software and Mission Control as to how much additional shielding is needed.
- 3) The AYSE drive has more effective mechanical shielding. Consider remaining docked to the AYSE drive while experiencing large radiation fluxes.
- 4) Both the HAB and the AYSE drive have large shield disks at the engine-nozzle end of the space craft. If the spacecraft is experiencing large directional radiation fluxes, aim the engine nozzles towards the source. This does not work against cosmic radiation or the radiation from a planet's magnetic field as these are non-directional.
- 5) Place a planet, asteroid, or comet between the spacecraft and a directional radiation source.
- 6) Enter a low orbit on a planet with a magnetic field. If the planet has an atmosphere, land for extra protection.

#### **1.6.5.5 HAB fuel Systems**

##### Monitoring

The HAB fuel system displays the current fuel load (kg) and the calculated fuel consumption rate (kg/h). The fuel system also displays the current HAB engine throttle setting from the piloting software.

##### Fuel Leaks

The actual fuel consumption rate should be calculated periodically by timing how long it takes to reduce the fuel load by some significant amount. This rate should be compared to the displayed rate. If the actual rate is higher than the displayed rate, a fuel leak is likely. The leak rate should be calculated.

Fuel sensors should be deployed on an IVA and/or an EVA to try to find and fix the leak. A mission abort may be necessary if the leak cannot be fixed.

##### Loading and Dumping Fuel

- 1) Close switch **3** to dump fuel from the HAB fuel tanks.  
If the HAB is docked with the AYSE drive, closing switch **3** will initiate a fuel transfer from the HAB to the AYSE drive. Monitor the fuel load until the desired load is reached.
- 2) Close switch **4** to load fuel into the HAB tanks.
  - a) if the HAB is at the OCESS launch pad, fuel will be loaded from the pad tanks.
  - b) if the HAB is docked to the AYSE drive, fuel will be transferred from the AYSE drive.
  - c) if the HAB is not at either of these locations or if the fuel tanks are full, switch **4** automatically opens.

##### Other Fuel Functions

Switches **1 & 2**: These switches control reaction mass fuel injectors to the HAB main engines. They must be closed for the HAB engines to function.

Switches **5 & 6**: These switches control the HAB reactor fuel injectors. They must be closed for the HAB reactor to generate electrical power.

Switch **7**: This switch controls the fuel injectors for the HAB fuel cell.

### **1.6.5.6 Other HAB functions**

- TAB** Displays the temperature of various components on the Orbit5Se user interface.
- `** Displays the current of various loads on the Orbit5Se user interface. The sum should be compared to bus current.
- R** Activates thermal roll program.  
Spacecraft will roll on its long axis to reduce heating due to solar radiation to any particular point on the spacecraft.
- Y** Parachute. The parachute aids in landing on planets with substantial atmospheres.  
Use of the parachute allows for lower total fuel consumption during landing.  
Important Points to Consider  
- the parachute has a very high drag ratio. Thus:  
    it will produce sudden and extreme acceleration changes if deployed at high speed and/or it will be destroyed.  
    the maximum safe speed depends on the density of the atmosphere.  
    performance testing will be necessary to construct a safe speed versus altitude for each planet.
- Z** Solid Rocket Boosters (SRB)

### **Detachable Module**

#### Detaching

- 1) Verify with pilot that the HAB spacecraft has landed in a stable location.
- 2) Shut down all engines.
- 3) Press switch **P** to detach longhouse module.
- 4) Verify with pilot and mission control that the longhouse module appears as a separate target in the target list and on the visual display.
- 5) Restart HAB systems as needed for mission profile.

#### Docking

- 1) Verify with pilot that the space craft has landed in a stable configuration within 100 m of the longhouse module.
- 2) Shut down all engines.
- 3) Press switch **Q** to dock the longhouse module.
- 4) Verify with pilot and mission control that the longhouse no longer appears as a separate target in the target list nor appears on the visual display.
- 5) Restart HAB systems as needed for mission profile.

### **HAB Docking**

This function allows the HAB spacecraft to dock with the ISS or other inhabitable vehicles.  
It does not contribute to the AYSE docking process.

- 1) Verify that the HAB spacecraft is in position with zero velocity relative to the docking spacecraft.
- 2) Shut down all engine systems.
- 3) Press **U** to arm the docking hatch lock. Indicator should show green.
- 4) Press **T** to lock the docking hatch. Indicator should show green.
- 5) Press **U** to disarm the docking hatch lock. Indicator should show blue.
- 6) Press **T** to verify that the docking hatch lock cannot be disengaged. Indicator should stay green.
- 7) Press **S** to open the docking hatch. Indicator should show green.
- 8) Verify with EECOM what airlock inner and outer doors show green.
- 9) Open inner and outer airlock doors.

#### Undocking

- 1) Verify that all crew have returned to the HAB spacecraft and all material and equipment have been removed to the HAB.
- 2) Close airlock inner and outer doors.
- 3) Verify airlock door status with EECOM.
- 4) Press **S** to close docking hatch. Indicator should show blue.
- 5) Press **U** to arm docking hatch lock. Indicator should show green.
- 6) Press **T** to unlock docking hatch. Indicator should show blue.
- 7) Press **U** to disarm the docking hatch lock. Indicator should show blue.
- 8) Restart engine systems.
- 9) Advise pilot that propulsion systems are ready for use.

## **AYSE Docking**

### **Auto Docking**

When pilot advises that     a) the HAB spacecraft is in a stable orbit (in case the docking is aborted), and  
  b) the HAB spacecraft is within 1000 km of the AYSE drive.

- 1) Shut down all engines on the HAB.
- 2) Activate AYSE engine systems (1.6.6).
- 3) Press **F11** to activate AYSE autodocking.
- 4) Wait until IN POSITION indicator shows green.
- 5) Proceed to step 14

### **Manual Docking**

- 10) Follow procedures 1.5.8
- 11) Wait until IN POSITION indicator shows green.
- 12) Verify with pilot that engines are no longer needed.
- 13) Shut down all engines.
- 14) Press F12 to arm docking latch. Indicator should show green.
- 15) Press ENTER to latch the HAB to the AYSE drive unit. Indicator should show green.
- 16) Press F12 to disarm docking latch. Indicator should show blue.
- 17) Verify that coupling indicator above TTC on the Orbit5Se interface shows a connection.
- 18) Verify that HAB throttle shows OFF and the AYSE throttle shows 0.0%.
- 19) If indicated in the mission plan, cross-connect the HAB and AYSE buses:  
    Press F1 and F2. Switches should show closed.
- 20) Start AYSE reactor and other systems if needed (1.6.6).

### **Undocking**

- 1) Verify that HAB power systems are in a stable configuration for self power.  
    Switch **z** should be closed and HAB reactor temperature should be in normal limits.  
    Switch **o** and **q** should be open and the secondary bus should be self powered.
- 2) Shut down all AYSE engine systems (1.6.6).
- 3) Shut down the AYSE reactor if required (1.6.6)
- 4) Open switches **F1** and **F2**.
- 5) Press F12 to arm docking latch. Indicator should show green.
- 6) Press ENTER to unlatch from the HAB. Indicator should show blue.
- 7) Press F12 to disarm docking latch.
- 8) Verify that coupling indicator shows disconnected.
- 9) Verify that AYSE throttle indicator shows OFF and HAB throttle indicator shows 0.0%.
- 10) Restart HAB engine systems.
- 11) Advise pilot that HAB is ready to undock from the AYSE drive unit.

## **Communications System**

The communications equipment draws power off of the secondary power bus.

Communications with OCESS mission control only is possible when switch **t** is closed and the secondary bus is at normal voltage.

### **Current Load**

The current drawn by the equipment varies with the distance to OCESS mission control. In earth orbit, even high earth orbits and in orbit around the moon, the secondary bus battery can sustain the load from the communications equipment.

Within the inner solar system, the HAB fuel cell will be necessary to supply sufficient power to run provide communications. Sustained communications using of the battery alone at these distances will result in damage to the battery.

Past the orbit of Jupiter, current load on the fuel cell should be monitored to ensure that the communications system is not drawing excessive current from the fuel cell. A drop in voltage on the secondary bus and an automatic opening of switch **p** cross-linking the secondary and tertiary buses is likely to be the first indication of excessive fuel cell current. At these distances, the secondary bus should be powered from the HAB reactor rather than the fuel cell.

### **Tertiary Power Bus**

Tertiary bus power supply is automatic and continuous. All loads on this bus are continuously powered as well.

If any repairs are needed to these systems, they must be isolated from tertiary bus within the circuit housing before repairs are attempted.

### **1.7.1 Mission Control Software**

**ORBIT5SM**: This is the mission control GUIDO station. It is the mission control version of Orbit5S. It has the same functions as Orbit5S, but acts as a telemetry display. It loads the OSBACKUP file saved by Orbit5S (over the network) every 5 seconds so that it displays a time-delayed image of the status of the habitat piloting software.

The telemetry function can be turned off so that Orbit5Sm can be used to evaluate different scenarios. These scenarios can be recorded and displayed on the screen during telemetry mode to determine how closely the habitat is following the predetermined orbital path (especially for launching from a planet). When displaying a pre-recorded track, the Orbit5Sm view must be centred on the same objects as when the track was recorded. If the HAB spacecraft is between points on the pre-recorded track, the distance from the track and the deviation from the pre-recorded speed at that point on the track is displayed.

Orbit5Sm specific commands        `x` toggle telemetry mode on/off  
                                      `y` toggle record mode on/off  
                                      `Z` display pre-recorded track (centre must be set to the same as when recording was made)  
                                      `z` redraw last recorded track (centre must be set to the same as when recording was made)

**ORBIT5ST**: This is the mission control GNC station (Guidance Navigation and Control systems engineer). It displays orbital telemetry (distance, velocity, Vcen, Vtan, ACC, engine throttle, fuel state, etc.) from OSBACKUP for the spacecraft relative to the reference object, the target object, and an alternate object that the mission control GNC officer can choose by pressing the appropriate code key (see 1.5.1.4).

The voltage and current for all of the buses and the current and temperature for each of the sources also is displayed.

By pressing **ENTER**, the GNC officer can view an display panel showing the state of the Orbit5Se engineering systems on the spacecraft. This interface is a display only, no switches can be changed from mission control. By pressing **ESC**, the display can be returned to the orbital telemetry.

**ORBIT5SF**: Once the program is started, load desired file, advance frame rate, record new file when desired time is reached, and alter the fuel state of the HAB and AYSE spacecraft.

**ORBCALC**: This program calculates time to destination in a high-energy transfer orbit based on current Distance to target and ACC parameters displayed on the ORBIT5S or ORBIT5Sm software.

This information can be used by GNC to evaluate fuel supply relative to rate of fuel consumption and duration of engine use. Time to destination also can be used to assist the EECOM officer in computing a predicted total radiation dose for a voyage.

There are two user inputs:   Vhab-ref  
                                  destination to target

Program Output:               time to reach destination.

After output has been displayed, press `q` to exit the software.

**Rad**: This software displays the radiation dose rate (Sv/s) at different altitudes from each significant radiation source within the solar system as well as the cosmic background rate.

User prompts:     **s**:     suit shielding  
                  **h**:     HAB shielding  
                  **a**:     AYSE shielding  
                  **m**:     add full magnetic shielding  
                  **d**:     add radiation shield disk  
                  **any number**: will calculate time to 1 Sv dose at that radiation level with the user selected shielding.  
                  **q**:     exit

**ORBIT5SD**: This utility displays telemetry data as well as a graphical depiction of the location of the HAB, AYSE, and ISS overlain on a map of current orbital location. The mission time and mission elapsed time also are displayed.

User prompts:     **target code**:   select background planet map to display (see 1.5.1.4 for list)  
                  **F12**:     input mission start time  
                  **ESC**:     exit

## **TRANSORB:**

This utility allows GNC to calculate low-energy transfer orbit parameters for GUIDO and the pilot.

The software calculates how much you need to change the speed of the spacecraft while in one orbit to initiate a transfer orbit to a new circular orbit about the same reference orbit. In other words, to undertake the maneuver illustrated in the following diagram:

You also can use it to determine how much to slow down to drop down to a new lower orbit.

***The software assumes that your current orbit is circular!***

If it is not, see the note in Program Output.

### Program Input:

- 1) Current orbit reference object (what you are orbiting) from a list.
- 2) Current altitude above reference object (km from the surface).
- 3) Ending altitude above reference object (km from the surface).
- 4) Planned engine acceleration.

### Program Output:

- 1) Required delta-V (change in velocity from ref  $V_o$  at current altitude).

This is the amount by which your current orbital speed must be changed (- means decrease, + means increase).

Add this amount to your current  $V_{hab-ref}$  and this is what your speed should be after your engine burn is complete.

***If your orbit is not circular, your new speed should be  $ref-V_o + \Delta V$ .***

***If your orbit is not circular, set target to equal ref. You also will have to zero out your  $V_{cen}$  while changing  $V_{tan}$ .***

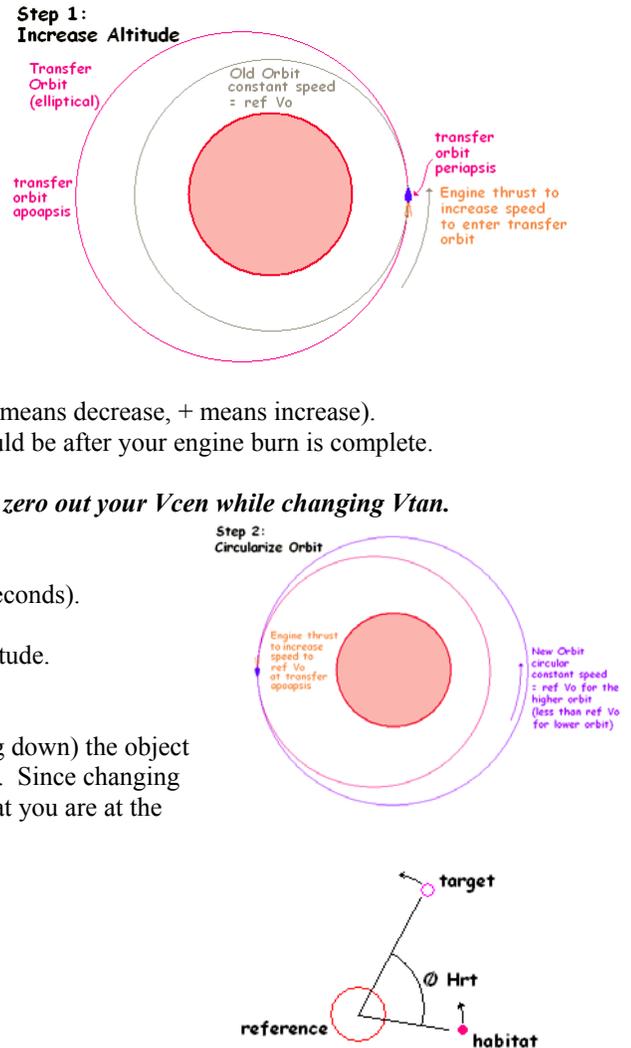
- 2) Engine burn time, assuming planned acceleration is used (seconds).  
This is for how long you will fire the engine to change your speed.
- 3) Transfer orbit duration; how long it will take to get to the target altitude (seconds).
- 4) Ref  $V_o$  of the new orbit.

This is how fast you will have to go to circularize your orbit at the new altitude.

This information is not critical until after the transfer orbit is complete.

- 5) lead angle ( $\emptyset Hrt$ ) needed to intercept a satellite in the target orbit.

This is by what angle you should be behind (or in front, if you are dropping down) the object with which you are trying to rendezvous at the moment you change the speed. Since changing speed will take time (engine burn time), you want to start the engines such that you are at the correct  $\emptyset Hrt$  half-way through the engine burn time.



This software only considers the effects of the gravity of the reference object. If there are other objects with significant gravity (such as the target, or the sun) affecting the spacecraft, Transorb will only give you a rough, first approximation of the correct delta-V and lead angle. For example, if you are rendezvousing with the moon, the moon's gravity will pull the spacecraft a bit faster and cause you to overshoot your desired apoapsis. If you are moving from one planet's orbit to another, the sun is the reference object that you must use, but both your departure and destination planet will pull at the spacecraft. The departure planet, in particular, will slow you down and cause you to undershoot your desired apoapsis.

## **2.0 Habitat General Procedures**

### **2.0.1 HAB Duty Officers**

The following HAB crew designations are used during the mission: HAB Mission Commander, HAB pilot, HAB copilot, HAB Tech Specialist, Payload Specialists. While there is a defined hierarchy of responsibility onboard the HAB, it must be realized that in a small, close-knit community such as this one, most non-critical decisions should be a matter of consensus. In particular, each member of the crew has a set of specific duties during the mission and should have the freedom to carry these out with the minimum safe level of supervision from the mission commander.

#### **2.0.1.1 Mission Commander**

The HAB Mission Commander has responsibility for and authority over all operations taking place in the habitat and on EVAs. This particularly includes ensuring that all operations under sections 2, 3, 4, and 5 conform to procedures set out in this manual. The mission commander is responsible for ensuring that all Alpha-class instructions from Mission Control are carried out. The Mission Commander must confirm that all non-Alpha-class instruction do not compromise the safety of the mission or crew before they are carried out. The Mission commander has the responsibility for supervising astronauts in their duties. The pilot (or copilot if the pilot is incapacitated) has the ultimate authority with regards to section 1.5. The Tech specialist has the ultimate authority over the procedures set out in P3.1, P3.3 and in the OCESS network procedures manual. Pilot and tech specialist should consult with mission commander regarding actions that could adversely affect mission outcome or crew safety. (see P1.1.3).

During EVAs when the astronaut mission commander is out on an EVA, a senior astronaut must be designated as acting mission commander for the duration of the mission commander's EVA. The acting mission commander must remain in the habitat until relieved by the mission commander. The acting mission commander assumes all of the duties, responsibilities, and authority of the mission commander until relieved by the mission commander.

#### **2.0.1.2 Pilot and Co-Pilot**

The pilot (or co-pilot if the pilot is incapacitated or off-duty) is responsible for all flight operations under section 1.5, including carrying out instructions or suggestions from GUIDO. Either the pilot and copilot must be onboard the spacecraft at all times.

#### **2.0.1.3 Tech Specialist**

The tech specialist is responsible for all habitat structures and systems (wiring, plumbing, computers, network, & cameras), their operation, and their repair. This includes section 3 and the OCESS network procedures manual.

#### **2.0.1.4 Payload Specialists**

These individuals have duties that are specific to a particular mission including experiments, collections, EVAs, and the shipboard duties common to all astronauts.

### **2.0.2 Mission Duty Stations**

Habitat duty stations are similar to those in Mission Control: **Mission Commander**, **Pilot**, **EECOM**, **CAPCOM**, and **AUXCOM**. These duty stations will have the same functions as the counterparts in MC (see P1.1). The Tech specialist combines the duties of INCO

During emergencies and critical phases of flight each of these duty stations will be occupied by one of the astronauts.

During non-critical phases of flight and while on the surface of the destination there will be a designated **Watch Officer** who will have the responsibility for monitoring communications, status of the flight management system, EECOM, and other ship status boards. The watch officer will have the responsibility for making log entries and for notifying the appropriate duty officer in the case of an emergency or discrepancy. Except for the period of time late at night, when MC will assume watch officer duties, there always should be an astronaut standing watch in the control center.

### **2.0.3 Mission Housekeeping**

It is the responsibility of the habitat mission commander, in consultation with other astronauts, to set up a rotating schedule of duties during the mission including: watch officer, meal preparation, meal clean-up, general cleaning, and regular ship survey. This schedule should take in to account the need for adequate personal time (outside of sleep time).

## **2.1 EVA**

**2.1.1 EVA:** Extra-Vehicular Activity. An astronaut puts on a self-enclosed environment suit, which is able to withstand the near-vacuum of space, the heat of solar wind (resistant to ionizing plasma charges of roughly 13,000V), radiation (reduction factor of the EVA suits is approximately 1:10,000), and most other unwanted hostile conditions. Defeating the suit's radiation protection while in a near-vacuum environment can result in skin burns, internal burns, blindness, sterility, and death. Except in the case of necessity during an emergency, EVAs should consist of **two astronauts**.

**2.1.2 EVA suit preparation:** Astronauts will need assistance in putting on the EVA suits. They should first take off as much unnecessary clothing as possible. Any supplies or equipment on their persons should be transferred to the EVA suits. The suit's inner layer is put on first. The full body suit is put on over top. Turn on the main power. Insert any cooling packs and activate any

fans. Close the outer suit layer with clips or clamps, cover over sealing points with Velcro flaps. Ensure that there are no leaks. Place the boots over the astronauts' feet, and seal them tightly onto the legs, clamping them in place. Use duct tape if necessary. Repeat for gloves. Duct tape should be limited to once around: excessive use can slow de-suited. Attach equipment to suit belts. Standard equipment is as follows: flashlight, duct tape, sample containment box, and headset. Attach the headset to the EVA suit, and turn it onto voice activation (VOX) mode. If necessary, use hair clips to attach the headset firmly onto the astronaut's head. Finally, after receiving the final go-ahead from Mission Control, attach the helmet onto the suit. Make sure there are no air leaks.

**2.1.3 Leaving the Habitat:** Once the EVA suits are complete and sealed, the Astronauts are to obtain clearance from Mission Control to enter the airlock. Once inside, they are to close the door behind them, and ask Mission Control to depressurize the airlock. Watch the airlock lights for clearance to leave. Mission Control will give the go-ahead to open the outer door. Leave through the door. The status report from the control center on airlock pressure status should be cross-checked against the airlock door indication panels before opening either airlock door.

**2.1.4 Entering the Habitat:** Once finished the EVA, approach the airlock. Check with Mission Control that it is indeed safe to open the airlock if it is now closed. Once informed it is safe, open the airlock and enter. Close the door behind you, and ask Mission Control to start pressurizing the airlock. Watch the airlock lights for pressure, although you must wait for confirmation from Habitat or Mission Control. During the pressurization process, the EVA astronauts should check each other for any potential hazards or sources of contamination. A confirmation from the astronauts that there are no hazards should precede the opening of the inner airlock door. Open the inner door and enter the Habitat. Any samples should be taken directly to the Hotlab by one of the other astronauts. The EVA suit should be swiftly removed in the reverse procedure from putting it on. The status report from the control center on airlock pressure status should be cross-checked against the airlock door indication panels before opening either airlock door.

**2.1.5 Surface Activities:** EVAs have four purposes: exploration, repair, emergencies, and scientific research. While exploring on an EVA, astronauts should describe what they see so that it may be recorded in Mission Control, and pick up any samples that they believe are of interest. While out on scientific research, the EVA usually will have a mission protocol, so the astronauts should run through whatever this procedure is. It can vary from setting up equipment, to gathering data, to whatever they may be interested in researching for the Mission. Emergency EVAs usually have a specific purpose. Often this is to go out and survey damage to the habitat. Sometimes they must repair damage or retrieve broken parts of the Habitat. In the worst case, they may be out on the surface to rendezvous with an emergency supply probe. A repair EVA is often a standard EVA to check and do maintenance to the Habitat, which is often hit by small meteorites; potentially threatening dents need to be repaired. "Emergency supply probes must be requested at least a day in advance, since the travel time is significant. Only call on such a request if something extremely critical is required and in a significant quantity. These probes are expensive to send up. "Space Sim Archives."

**2.1.6 Astronaut Recovery:** Once an astronaut has completed his/her EVA, biomedics should be taken (P2.5.3) and transmitted back to Mission Control. Ensure that the astronaut has not suffered from any adverse conditions (heat stroke, exhaustion, suffocation, etc.) Give the astronaut time to rest, as an EVA is very tiring. Also, have a glass of cold liquid ready to give them as soon as they get out of the suit. This may sound trivial, but if you're in an EVA suit, you'll understand.

## **2.2 IVA**

**2.2.1 IVA:** Intra-vehicular Activity. An astronaut puts on EVA suit (P2.1), but uses it to conduct procedure inside the Habitat.

**2.2.2 IVA suit preparation:** The IVA suit is an EVA suit. Don the EVA suit as outlined in P2.1.2

**2.2.3 Moving around the Habitat:** When entering or leaving a module, ensure that opening the door will not pose a risk to the other astronauts. Mission control will inform you as to whether or not it is safe and what the other astronauts must do to ensure they are safe. Try to limit unnecessary movement to avoid overheating.

**2.2.4 IVA activities:** If you are performing an IVA, it is due to unforeseen circumstances. There may be loose, live wires. A module may have been depressurized. You may need to enter an area full of high radiation. Follow Mission Control's instructions carefully. If communication with Mission Control is broken, try to re-establish it as soon as possible.

**2.2.5 Emergency IVAs/EVAs:** During most emergency IVAs/EVAs, contact with Mission Control is sketchy at best.

## **2.3 EXPERIMENTS**

**2.3.1 Experiment:** Any activity of which the purpose is to retrieve data and send it back to Mission Control.

a) Experimental procedures and protocols must be established, **approved by the teacher advisor**, and recorded prior to pre-launch planning. Each astronaut is responsible for a set of experiments and confirming that all necessary supplies are on board prior to launch.

b) Procedures should consist of numbered steps and a decision tree to follow based on possible results. Deviations from established procedures must be communicated to MC approved by the teacher advisor prior to their being carried out. This may necessitate the flight director contacting the teacher advisor by phone at school or at home. **No one except the teacher advisor**

**can approve changes to experimental procedure.** The procedures should include safety equipment and protocols and a list of any specific safety issues connected with the procedure.

c) All equipment and materials (in approved dispensers) should be set out prior to starting an experiment. It also should be ascertained that the necessary samples are available.

d) Experiments will have specifically detailed procedures that will produce results (success or failure, plus specific data). These results should then be transmitted back to Mission Control.

**2.3.2 Transmission of Results:** The current astronaut on CapCom should announce that the experiment results are being sent. The INCO astronaut will then type the results through AuxCom to ensure reliability of transfer. Mission Control will take down these results onto a safe file. A hard copy of the results should be printed in case of system failure.

## **2.4 HOTLAB**

**2.4.1 Hotlab:** The Habitat's self-contained laboratory. It is used to perform experiments that would possibly pose a risk to the safety of the astronauts if they were performed in the open due to contaminants. It also is the storage location for dangerous items.

**2.4.2 Preparation:** When called for, the astronaut performing the experiment will suit up in a biohazard suit (or, if none are available, an EVA suit). Follow the procedures outlined in P2.1.2[EVA suit preparation]. For all intents, a Hotlab experiment can be considered a non-emergency IVA (as outlined in P2.2[IVA]). Note: The Hazard Suit is necessary if direct contact will be made with samples or if samples will be open to the atmosphere of the hotlab. In the case of open samples, the hotlab door must be sealed and the high capacity vent fan must be set to full speed..

**2.4.3 Experiment Procedure:** Experiments may be performed using the procedure outlined in P2.3[Experiments], with added precautions taken to minimize the possibility of a hazardous material being spilled. Environmental conditions in the Hotlab should be constantly examined to reveal the effects, if any, of the materials.

**2.4.4 Completion:** The astronaut will return to the Habitat only once all possible hazardous materials have been sealed off. Experiment results should be transmitted to Mission Control as outlined in 2.3.2[Transmission of Results. If there is any chance that the astronaut was exposed to hazardous materials, they must be quarantined under P2.5.6 and monitored.

**2.4.5 Hotbox:** The Hotbox is the Hotlab's small containment unit. Samples are to be placed (still inside their containment box) into the door on the right. This door must be shut before the inner door is opened. The Astronaut is to then place his or her hands into the arms of the Hotbox. He or she is to open the inner door and retrieve the sample. It is safe to open a sample inside the Hotbox. There are a number of cabinets inside the Hotbox. The Astronauts should be aware of where they can keep samples, and where the chemicals they'll need are located. Samples are only to leave the Hotbox inside a containment box or after they have been determined benign. Alternately, samples may be passed directly into the hot box from outside the habitat using the sample hatch. **During experiments, EECOM should monitor the hotbox camera feed for signs of danger.**

## **2.4.6 General Procedures for Analysis of Samples**

Procedures and equipment for standard analytical tests are kept in the main storage lockers in the control room.

**2.4.6.1 Acidity Test:** Complete a simple pH paper test on the sample. Strongly Acidic or Basic substances should remain in the Hotbox. The Hotbox should be stocked with the appropriate supplies. Sediment samples can be tested by titration analysis.

**2.4.6.2 Microscopic Analysis:** Samples can be removed from the Hotbox, if safe, and viewed under a microscope. No procedure is given for making of thin-section slides, as samples will be returned to earth for this type of analysis.

**2.4.6.3 Radiation Test:** If available, a Geiger counter may be used to check radioactivity. Radioactive substances should not leave the Hotbox without mission control clearance.

**2.4.6.4 Luminescence Test:** Shine bright lights onto the samples to see if they react to light in any way.

**2.4.6.5 Geological Tests:** Instructions and materials for these tests (hardness, streak, crystal form, reaction with HCl, colour, etc.) are stored in the main storage area in the Interlock. Durability tests (breaking a sample with hands or tools) only is to be conducted in the Hotbox as unknown gases may be released from the centre of the sample.

## **2.5 BIOMEDICAL OBSERVATIONS AND ASTRONAUT HEALTH**

**2.5.1 Description:** The astronauts must maintain their physical and mental health throughout the mission.

**2.5.2 Cycling:** All astronauts must cycle for at least half an hour per day. This will be scheduled by the Mission Commander. They may cycle at whichever pace they can maintain but are encouraged to push themselves. The Astronauts are to have their biomed (P2.5.3) taken before and after the cycling as well as one other time during the day.

**2.5.3 Biomed:** If the astronauts must take their 'biomed' this means they must check their blood pressure, pulse, temperature, and mass. To test blood pressure and pulse, strap the automated apparatus to arm, turn it on, push ready, then remain as still as possible until the check is complete. Let the apparatus pressurize, wait for the apparatus to get readings, get readings of screen on apparatus. Use the digital thermometer to test temperature, and use the accelerometer scale to test mass. All biomed readings are to be logged, including baseline observations prior to launch. Any other symptoms and signs also must be logged, especially those related to exceptional gravity regimes (edema, back and joint pain) and long-term confinement. Any significant departures from baseline measurements should be reported to Mission Control immediately.

**2.5.4 Nutrition:** The Astronauts must be properly nourished. They are to eat three meals a day. All food is predetermined before the mission. Available 'snacks' are also predetermined. No extra food is to be brought on the mission. Food will be prepared in advance of meal time (duty Scheduled by Mission Commander) and cleaned up by other astronauts immediately afterwards. Astronauts should keep consider the limited capacity of the toilets in meal planning.

**2.5.5 Fatigue:** Fatigue levels should be kept to a minimum. The astronauts do have an appointed time each day at which they are supposed to sleep. Recommended sleep time: 8 hours. Mission Control will enforce this if fatigue problems are encountered.

**2.5.6 Quarantine:** If an astronaut is ill, or is hurt, he/she is to be quarantined. The Hotlab is ideal for this purpose, as it has a decontamination field. If the astronaut is required to move around or participate in group activities, he or she is to put on an EVA suit, so that he or she remains in an isolated environment. (see P4.4)

## **3.0 GENERAL EMERGENCY REFERENCE PROCEDURES**

### **3.1 HABITAT ELECTRICAL**

**3.1.1 Power Failure (complete)**: Follow P4.22 (Beta Evac Only), and then consult Tech Specialist or P4.7.3 (Total Power Restoration). Flashlights always should be mounted in their wall mounts by the fire extinguishers in all modules. Contact MC over the hand-held communication system. A light source should be kept ready for use near the two auxiliary power outlets: under router in Interlock and under kitchen counter below microwave oven.

General Power Failure @ OCESS building site requires an **Alpha Evacuation** (P4.3)

**3.1.2 Power Failure (single module)**: Evacuate affected module immediately, then consult Tech Specialist or P4.7.2.

**3.1.3 Repetitive Power Loss**: Initiate P4.2.3 (Beta Isolation). The HAB Commander and Tech Specialist will gather in the Interlock and follow P4.7.5 (Repetitive Breaker Tripping)

**3.1.4 Arcing or Sparks**: Initiate P4.2.3 (Beta Isolation). Contact Mission Control and proceed with P4.32 (Alpha Extreme Hazard Evac) unless cleared to follow P4.7.4 (Terminating Power). Once power is terminated, the situation will be assessed. P4.3.1 (Alpha Evac) may be ordered depending on the affected module. Only **grounded** or **double-insulated/grounded-to-neutral** devices are allowed in the habitat. This restriction, and the common grounding of all habitat frame structures should prevent arcing.

### **3.2 HABITAT ENVIRONMENTAL**

Sections **3.2.1**, **3.2.2**, and **3.2.3** **must** be memorized by the crew and mission control staff through pre-launch training and post launch drills.

**3.2.1 Minor Fire**: Follow P4.1(Habitat Fire Control), followed by P4.3(Alpha Evac) if deemed necessary.

**3.2.2 Major Fire**: Follow P4.3 (Alpha Evac).

**3.2.3 Radiation**: Follow P4.2.1 (General Beta Evac).

### **3.2.4 EECOM**

#### **3.2.4.1 Atmospheric Warnings**

The status of each module is indicated by colour on the graphical display and on the gas data line for each module. Hazardous conditions in a module are indicated by a yellow color on the graphical display. Critical or lethal conditions are indicated by a red color. Corrective actions can only be made to the currently selected compartment. Once enacted, a new compartment can be selected and processes running on other compartments are not affected. Compartments can be selected using the up/down arrow keys. The selected module is indicated by a solid background, the others by a dotted background.

#### **3.2.4.2 Door Warnings**

Door status is indicated on the graphical display and on a data line for the selected door. Doors can be selected using the left/right arrow keys. - Latched doors are indicated by a double line.

- Unlatched doors are indicated by a gap.
- Doors which are malfunctioning and may fail are indicated by a red colour on the double line and on the data display.
- Doors with dangerous pressure differences on either side are indicated by a red background when selected, otherwise the background is white.

Doors can be latched or unlatched using the EECOM control panel. Doors can not be latched if they are not physically shut. If shut, but not latched, air can pass through the door as if it was not shut. Doors are latched or un-latched using the 'ENTER' key.

Doors can not be unlatched if a dangerous pressure difference exists across the door, unless the override is selected ('\*' key).

Doors that show potential malfunctions should be checked and physically adjusted. After adjusting the door, wait to see if the warning indication returns to normal. If not, and if the door has a dangerous pressure difference, consider evacuating the compartment, sending in a tech specialist, and adjusting the compartment pressure so as to be able to open the door.

#### **3.2.4.3 Removal of Hazardous Contaminants**

Hazardous contaminants can be removed by venting air and re-pressurizing the compartment. This method will not be effective if the source of the contaminants have not been removed first. Venting can be manual ('-' and '+' keys) or automatic (venting stops at zero pressure, re-pressurization stops at 101.32 kPa) (F11 and F12 keys). Re-pressurize modules using the pressurization system for that module rather than opening doors to other modules.

If contamination is severe, a Beta Evacuation and IVA may be used.

Air can be moved between modules by selectively opening doors and adjusting air pressure. This can be useful for containing contaminants within particular modules without having to seal the module.

#### **3.2.4.4 Correcting Atmospheric Conditions**

The levels of CO<sub>2</sub>, water, and dust are maintained using a system of scrubbers, filters, and supply systems. These systems can be overcome by extreme conditions within a module: heavy construction activity, too many crew-members working in one module, or activities involving open water. When this occurs, CO<sub>2</sub>, water, or dust levels may begin to climb. If this happens, supplementary systems can be manually activated using the EECOM system to correct the imbalances. However, the cause of the problems should be investigated and corrected, if possible:

- evaluate the way the compartment is being used
- check for any open containers or spills
- check for any leaks in pressurized gas pipes
- check that the primary CO<sub>2</sub> scrubbers, humidifiers, and dust filters do not need their cartridges or filters replaced

Keys for the supplementary CO<sub>2</sub>, water, and dust management systems are indicated in the EECOM display. The functioning of these supplementary systems is indicated on the panel below the primary gas data panel.

### **3.3 HABITAT ELECTRONIC**

#### **3.3.1 Control Panel** <pending panel restoration and installation>

#### **3.3.2 Computer Systems and Secondary Communications (INCO):**

Auxcom is the responsibility of INCO. Other network COM systems may be available. Consult INCO for computer systems issues. All other network issues should be referred to the OCESS network procedures manual.

#### **3.3.3 Cameras:**

All Corel camera signals are routed to MC through the router in the Interlock (see 1.3.5). If a fault occurs, see 1.3.5 and 3.5.3. If faults cannot be corrected using these procedures, INCO and HAB staff must check network cable connections for sound and proper connection.

#### **3.3.4 Primary Communications (CAPCOM)**

CAPCOM uses radio headsets and Digital VOX (handset) to communicate with the HAB and MC. This system depends on the proper function of the TCS and dish antenna. (see 3.5.1)

### **3.4 HULL BREACHES**

Follow P4.2.1 (Beta Evac). Check air pressure readout panel at each door or at the EECOM panel before opening it.

#### **3.4.1 Critical Decompression**

If rapid decompression occurs in any module, immediately evacuate the module and seal it off.

#### **3.4.2 Non Critical Decompression**

Declare a Beta Emergency evacuation of the affected module.

Turn off all non-flight systems in the module but do not cut power to the module.

Move to a module with one non-critical module separating from the critical module (if possible).

Repair crew suit-up in preparation for IVA repair mission.

**3.4.2 Identification of Hull Breaches:** Hull breaches may be identified through either visual inspection of the hull or pressure drops in any parts of the Habitat monitored by EECOM. The fundamental principle of hull breaches is that it is better to be safe than sorry: any indication whatsoever of a hull breach should be treated as a definite atmospheric leak until it is proven otherwise.

**3.4.1.1 Search:** Perform a visual inspection for holes and for motion of dust and debris within the module. If the module is completely depressurized, the breach probably is large enough to see easily. If not, consider running the pressurization pumps for a short period of time.

If the module has pressure, use of a spray mist device may aid in finding small leaks. Spray the mist near the wall where the leak is suspected and watch for motion of the mist. Do not use the mist spray near electrical devices or outlets. If the module has sufficient pressure to enter without EVA helmets, leaks may be evident by listening.

**3.4.3 Hull Breach Sealing:** Two astronauts, if possible, must go on an EVA (P2.1) as soon as the situation permits. They must take all necessary repair equipment (tools, aluminum tape, spare patching fabric and compound, and fasteners). Equipment and instructions for use are located in the main storage bays in the interlock. Practice drills must be conducted prior to the mission. Preparation of hull patches should be carried out prior to donning EVA suits, if possible as the knives are difficult to handle with EVA suit gloves. Consult the Hull Breach Repair card mounted on the wall of the control room near the airlock door.

**Small openings:** (1 cm or less) can be repaired by pressing drywall compound into the hole and around the perimeter. A strip of drywall paper is placed over the compound and pressed flat to the wall.

**Large openings:** must be repaired using the following protocol.

- 1) square the opening with a drywall knife
- 2) cut out a piece of drywall larger than the squared opening
- 3) score a square the same size of the squared hull opening in the center of one side of the piece of drywall
- 4) peel off the paper around the outside of the scored square
- 5) crack the drywall around the edge of the scored square
- 6) remove the drywall around the edge of the scored square
- 7) you will be left with a square of drywall the same size as the opening with a flap of paper extending out on all edges on one side of the patch.
- 8) smear drywall compound around the flap of paper and along the edge of the drywall square of the patch.
- 9) press the patch into the opening and press the paper flap with the drywall scraper

### **3.5 COMMUNICATION PROBLEMS**

**3.5.1 Total Failure:** Communications may have been disrupted by ion, lightning, or sand storms on the planetary surface. If this is the case, attempt to re-establish contact at thirty seconds. Communications should be possible once the storm has abated. If lost after a meteor strike or shower, it is likely that the TCS dish has been damaged. Once you are certain the meteor shower is over, an EVA (P2.1) should be performed to examine the dishes and repair them if necessary. The digital VOX system (telephone handset) often will function even when all other COM systems are down.

**3.5.2 CAPCOM Failure:** Attempt to maintain contact via AuxCom or the digital VOX communication system (telephone handset) if this is functioning. Check headset and VOX system batteries. Interference or disruption may be due to storms or meteors, as outlined in P3.5.1. Attempt to re-establish contact once every thirty seconds.

**3.5.3 Visual Link Failure:** If a single camera or TV goes down, it is most likely faulty. Push the orange button on its console. Failing this, contact Mission Control for the resident Camera Specialist (usually Tech Director or INCO) and receive instructions for replacement. If all the cameras go down:

**Habitat crew:** check the TCS dish (P3.5.1, requires EVA) and the router (Interlock, above and to the left of the airlock door). If the router is not functioning, check the power cord (both ends) and the status of the auxiliary power circuit.

**MC INCO:** check the following are running: the router, the network server (Calibre), the Corel camera server (Stonehenge), or the Corel camera network software. If the either server is down: restart. Consult the OCESS Network Procs. Manual for procedures and passwords.

**3.5.4 Auxcom Failure:** If Auxcom goes down, but Capcom is still online, it could be a network packet error. Interplanetary networks have a good chance of losing large numbers of network packets. Co-ordinate with Mission Control to re-establish the link through INCO (or telnet and talk if INCO is not working).

**3.5.5 Total Message Loss:** If Capcom and Auxcom are down, use the Cameras and hand signals to inform mission control of your situation. Write on paper and hold it up. The Flight will give a “thumbs up” if he can understand or “thumbs down” if he cannot. Mission Control is to respond in a similar manner, writing on paper. If prolonged loss of messages occurs, the Camera System can be rigged for audio transmission, but this should be avoided at all costs, as the connection is bad and causes feedback.

### **3.6 NAVIGATION ERRORS**

See P 1.5 for general procedures for ship and navigation systems.

#### **3.6.1 Automatic Navigation System Malfunction**

See P1.5.11 section B to restart the navigation computer.

While attempting to reset the navigation computer, use manual orientation to stay on the flight profile.

Navigation failures are indicated by colour change (red) on the navigation orientation readout.

### **3.6.2 Off Course on Transfer Orbit**

#### **3.6.2.1 Small Deviations**

During a high energy transfer orbit, the velocity vector and target vector should be superimposed and  $V_{tan}$  should be near zero. If this is not the case, select manual orientation and rotate the space craft 1 to 5 degrees opposite to the direction of the deviation. Return to automatic orientation when the deviation is reduced sufficiently.

#### **3.6.2.2 Large Deviations**

If the space craft is seriously off course at high speed, do not attempt to alter course before excess speed is reduced. Orient the space craft manually to face away from the direction of motion. Use maximum thrust to reduce speed to a proper level. Once on speed, orient the space craft towards the target and apply thrust to bring the velocity vector towards the target vector. Once near the correct velocity direction, go to 3.6.2.1 to refine the velocity vector.

#### **3.6.3 Off Speed on Transfer Orbit or Landing**

If on the second leg (slowing to a stop) portion of a high energy transfer orbit and the ACC value exceeds the maximum engine output, there are three options, depending on the distance from the target.

A) If a great distance from the target, use maximum continuous engine output away from the target. Use an orientation that keeps a small deviation in direction off to one side of the target. When close to the target, use 3.6.3 part B.

B) Near the target (less than 5 million km), adjust velocity vector so that orbit projections shows a near miss of the target. Confirm this with GUIDO's longer-range orbit projection. Use manual orientation to hold an orientation exactly opposite the velocity vector, NOT the target vector. This is especially important as you pass the target. When the velocity vector swings around to approach the target vector, then proceed to P3.6.2.2 to correct the velocity vector.

C) At close range to the target, orient the space craft as near sideways as you can and apply maximum thrust until orbit projection shows that the space craft will miss the target. At that point, orient opposite to the velocity vector and apply only as much thrust as needed to cause the orbit projection to wrap around the target. At apoapsis, use retrograde (ccw retrograde if in a ccw orbit or cw prograde in a cw orbit) or prograde thrust adjust the velocity until the desired periapsis is projected. Go to P1.5.2 if needed.

D) When in final descent to landing, orient at around 45 degrees up from the horizon and use full engine output. The aim is to increase  $V_{tan}$  enough to enter a low orbit rather than landing. If you are too close to landing to re-enter orbit, apply maximum upward thrust and follow P3.8 to prepare for impact.

#### **3.6.4 Engine Failure**

Use P 1.5.11 to address engine problems. Engine failures are indicated by colour change (red) on the engine readout.

Ship systems failures that reduce engine output can result in speed and direction errors. After the failures are rectified, go to section 3.6.2 and 3.6.3 to address these issues.

Partial Engine failures show the same colour change on the readout, but engines will work with a reduced maximum output.

If AYSE drive engines do not work at full output ( $200 \text{ m/s}^2$ ), but no engine failure is indicated, check the antigravity systems and thermal roll indicator. Engine maximum output is reduced when these systems are not on.

### **3.7 Breach of Suit Containment**

#### **3.7.1 Temporary Repair**

Apply temporary sealant (duct tape) to effected area.

Inform Habitat commander.

Return to Habitat as soon as possible (P2.1.4).

#### **3.7.2 EVA Rescue**

If return to habitat is not possible, request rescue.

Before loss of suit power or consciousness, provide detailed information on circumstances and any circumstances that might endanger the rescue party or habitat at large.

### **3.8 Asteroid Impact Warning**

Asteroid impact warnings are routed from navigation radars to the EECOM system. This is because there is little that the space craft can do to avoid asteroids at the closure speeds normally encountered and the short detection distances involved. As such, it is more important to configure the space craft to survive impacts.

### **3.8.1 Impact Preparation**

The following steps should be taken.

- 1) Designated engineering specialist dons EVA suit and prepares for IVA (P2.1)
- 2) Gather all repair tools and materials for quick use
- 3) Suited personnel and repair equipment remain in interconnect module
- 4) Secure all loose objects
- 5) Turn off all non-essential equipment
- 6) Commander and pilot remain in interlock command center
- 7) Pilot places habitat into a stable flight mode in case the command center must be evacuated
- 8) Disperse all other crew into other modules
- 9) Latch all doors and verify latched status on EECOM panel

### **3.8.2 After Impact**

Hull breaches are a likely result of an impact (P3.4). Mission control and HAB staff should monitor EECOM to assess this threat.

Electrical lines and other distributed systems may be compromised and need to be fixed. Designated crew members should use flashlights to inspect carefully all areas of the habitat.

The pilot or copilot should assess the status of all flight systems and ascertain that the space craft is still on course and that the engine capacity is sufficient to enter orbit at the destination.



#### **4.0 EMERGENCY ACTION PROCEDURES**

Sections **4.1**, **4.2**, and **4.3** **must** be memorized by all personnel through pre-launch training and post launch drills.

#### **4.1 HABITAT FIRE CONTROL**

All astronaut crew must demonstrate working knowledge of section **4.1** and **4.3** prior to launch.

**4.1.1 Habitat Fire Control (General):** *Inform Mission Control by any method possible IMMEDIATELY.* If the fire is localized in one small area, initiate a Beta Evacuation and seal off that area (P4.2.1) Use fire extinguishers on small fires (P4.1.1.1 A). If the fire appears life-threatening (P4.1.1.1 A&B), the Mission Commander will declare an Alpha-class Emergency. This is to be relayed to Mission Control as soon as possible. Immediately follow with a total evacuation of the Habitat (P4.3).

**4.1.1.1 Fire:** Real Fire Emergencies, outside the parameters of the simulation exercise fall into two classes: small fires and large fires. The decision to treat any fire as small or large must be made *immediately*. Either the astronaut mission-commander, flight director, mission control commander, or teacher advisor (or designate) can impose a large fire designation on an emergency situation. **Once declared a large fire, an emergency CAN NOT be re-classified.**

**A) Small Fires** can be extinguished using the fire extinguishers in the habitat with the following considerations.

**The decision to classify as a small fire must be made immediately.**

**If there is any uncertainty, the emergency is to be classed a large fire.**

**Any fire at an emergency exit or near the power control box will be treated as a large fire.**

**If more than one extinguisher fails to operate, the emergency will be re-classified as a large fire.**

**If the extinguishers fail to extinguish the fire, the emergency will be re-classified as a large fire.**

A small fire drill must be held during the outward leg of the mission to familiarize all astronauts with the proper use of the fire extinguishers and evacuation routes. When fighting a fire: aim the fire extinguisher near the base of the fire, trigger the extinguisher, move the exhaust of the extinguisher back and forth across the base of the fire until it is out.

**B) Once a Large Fire** is declared,

1) **a general evacuation will be initiated** (P4.3)

2) **the building's fire alarm will be activated.**

**Evacuation procedures must be posted in mission control and in the HAB's control room.**

#### **4.2 HABITAT BETA EVACUATION**

**4.2.1 General Procedure:** All Astronauts are to immediately move to a non-endangered module, preferably the Interlock, or a module as close to the Interlock as possible, sealing all doors and hatches behind them to minimize the number of endangered modules. Under no circumstances should Astronauts be split into groups except (a) to conduct IVAs/EVAs or (b) when rendered impossible when astronauts are separated by depressurized or otherwise endangered modules.

#### **4.2.3 ISOLATION**

This action plan is to be used for any instances of wide-spread: contamination (chemical or biological), illness, or ship malfunction (e.g., electrical, environmental). This plan is only to be implemented when the HAB is in contact with Mission Control and can communicate the details of the emergency to MC. The purpose of this procedure is to allow MC time to devise a safe plan for correcting the situation.

**4.2.3.1 Procedure:** Terminate all activities immediately. All Astronauts must remain in their current modules and under no circumstances are they to move. Astronauts should sit on the floor and avoid any contact with the rest of the hull. The Habitat Commander will enter the Interlock and resume control of the HAB only when cleared to do so by Mission Control.



### 4.3 HABITAT ALPHA EVACUATION

The teacher advisor or supervising shall maintain a list of all students in the OCESS spaces at all times.

**4.3.1 GENERAL Procedure:** This is a full evacuation of the Habitat modules. All astronauts, MC staff, and simulators are to exit immediately by way of the predetermined escape routes. **The teacher advisor or designate shall be the last to evacuate.** Marshalling area is on the south side of Albert Street. At this time the student list shall be consulted to ascertain that all students are present. At the earliest safe time, student will cross to the other side of Albert Street. The following evacuation procedures are for prescribed **fire emergencies**, but are to be followed for any localized hazard such as **hazardous material spills** and **electrical hazards**.

**4.3.1.1 Primary Evacuation Routes:** Fire is not in the OCESS spaces.

**Mission control:**

Proceed out the door to the hallway, turn to the right, up the stairs and out the door to the Albert St. sidewalk.

**Planetary Surface / Sim Work Areas:**

**Issues:** Shuttle may block passage in front of the west door to MC.

Planetary surface features may slow exit through east door to MC.

**Do not attempt to cross through the space shuttle mock-up by the west door to MC.**

**Sim Work Areas**

Proceed around north side of longhouse or along the side of the Interlock and washroom directly to exterior door out to Albert St. and Lyon St.

**Planetary Surface**

Proceed to Sim Work area along the east side of the Interlock directly to the exterior door out to Albert and Lyon street.

**Habitat:**

**Longhouse & Washroom:** out the longhouse exit door, turn right, up the stairs and out the exit door.

**Interlock:** Proceed into longhouse. Follow longhouse evacuation route.

**HotLab:** Fire outside the habitat, proceed through Interlock into Longhouse. Follow longhouse evacuation route.

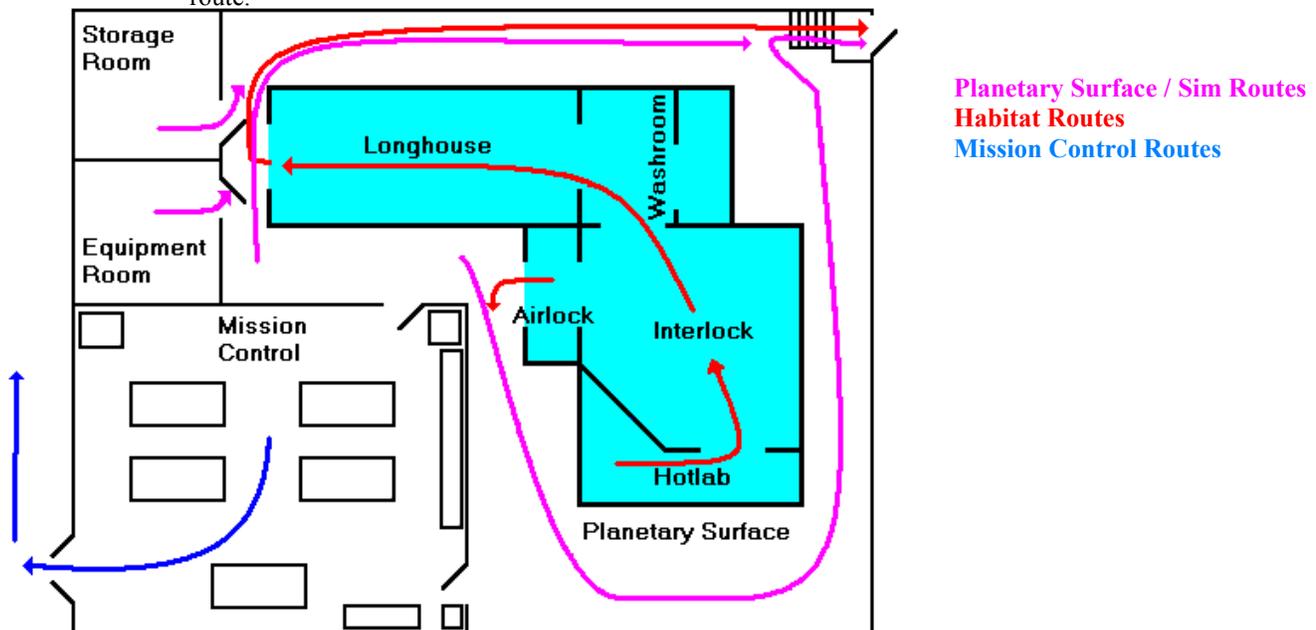


Figure 1: Primary Evacuation Routes



**4.3.1.2 Secondary Evacuation Routes:** Fire in OCESS spaces

**4.3.1.2.1: Fire Outside of the Habitat:**

**A) Fire outside MC door to corridor or in MC near the door.**

**Mission control:**

For fires in the hallway area, proceed through the east door to the planetary surface and follow Planetary Surface evacuation route.

**Habitat, Planetary Surface, and Sim Work Areas:**

Follow primary evacuation routes.

**B) Fire blocking exterior door to Albert and Lyon streets.**

**Mission Control**

Follow primary fire evacuation route.

**Habitat**

Proceed to airlock. Proceed out of the airlock onto the planetary surface and into MC via the east door. Follow primary MC evacuation route.

**Planetary Surface**

Proceed through east door to MC. Follow primary MC evacuation route.

**Sim Work Area**

In the Sim area east of the Interlock, proceed to planetary surface and through east door into MC. Follow primary MC evacuation route.

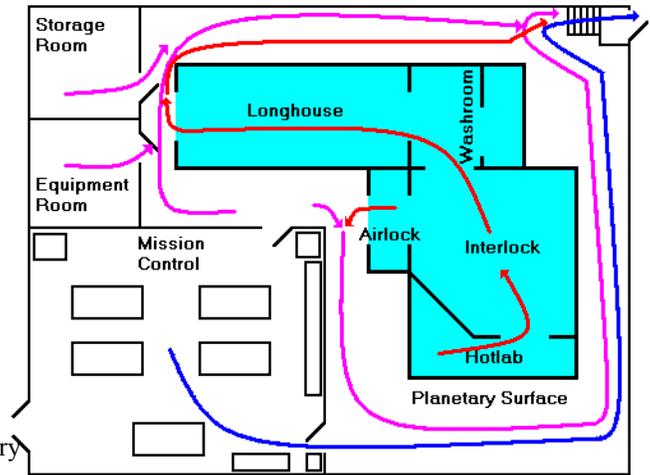
In the Sim area around the longhouse, proceed into the longhouse and through to the airlock. Proceed out of the airlock onto the planetary surface and into MC via the east door. Follow primary MC evacuation route.

**C) Fire in the Habitat**

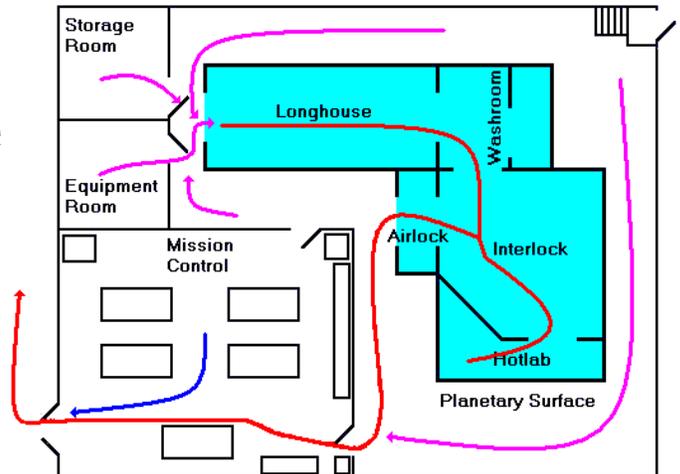
Outside of the habitat, follow evacuation procedure (A)

Inside of the habitat, proceed away from the fire towards the nearest exit: longhouse exit, airlock, or hotlab breakout panel.

Once outside of the habitat, Follow Figure 2 secondary evacuation routes. **Figure 2: Secondary Evacuation Routes**



**Figure 2: Secondary Evacuation Routes**



**Figure 3: Secondary Evacuation Routes**

**D) Fire in Mission Control, Planetary Surface, or Sim Work Area not covered by (A) or (B)**

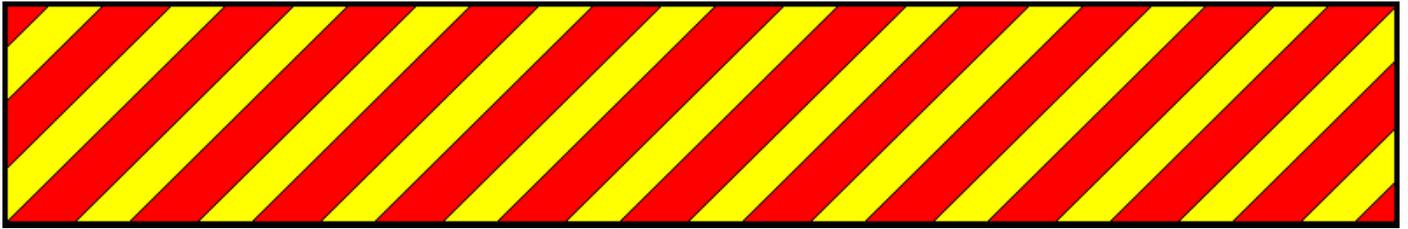
i) If the fire is on the planetary surface, all staff and students will follow figure 2 secondary evacuation routes except those on the planetary surface. Those on planetary surface will proceed through east door to MC or through exterior door to Albert and Lyon streets depending on location of fire.

ii) If the fire is in the Sim Work area, all staff follow Figure 3 secondary evacuation routes except those in the Sim Work Area. Those in the Sim work area follow either figures 2 or 3 secondary evacuation routes depending on location of fire.

iii) If the fire is in Mission control, MC staff will proceed away from the fire towards the door to the corridor or out the east door to the planetary surface and follow planetary surface evacuation route. For all other locations, follow Figure 3 secondary evacuation routes.

**4.3.2 EXTREME HAZARD Procedure:** Evacuate Habitat by the closest route, avoiding any damaged, malfunctioning, or contaminated modules, taking extreme care to not touch the hull at any time.

**4.3.4 EVACUATION AND SEALING Procedure:** As each module is evacuated, it is to be sealed off from the rest of the Habitat, taking care to not obstruct other astronauts' escape routes. The Mission Commander is then to terminate all power systems (P4.7.5), and proceed with evacuation P4.3.1.



#### **4.4 ASTRONAUT ILLNESS/INJURY**

The Canadian Red Cross First Aid Manual shall be set out on the Flight Director's desk at all times during the mission.

##### **4.4.1 GENERAL Procedures:**

Classes of illness/injury: 1) **Beta situations**: illness/injury within the parameters of the simulation  
2) **Alpha situations - minor**: real incidents that can be handled within the simulation  
3) **Alpha situations - major**: real incidents requiring the removal of an astronaut from the simulation  
4) **Alpha evacuations**: critical/life threatening incidents requiring the simulation to be aborted

Each alpha situation must be evaluated separately in direct consultation with the teacher advisor or designate.

In the case of class 1 or 2 situations, keep the affected astronaut(s) comfortable and attempt treatment as applicable. Use sections P4.4.2 to P4.4.3 and the First Aid manual in MC in dealing with these situations.

Any Alpha significant illness, including fever, must be considered class 3 situations.

In the case of serious injury or illness:

- 1) Notify Mission Control
- 2) Astronaut will be declared 'dead'
- 3) Astronaut will be placed in the airlock.
- 4) see P4.4.4

In case of an Alpha life-threatening injury or illness, the mission will be aborted and the advisor will contact EMS and directly assess the situation. The casualty should not be moved except by EMS or when the location itself is an immediate threat to life.

**Mission Control should be notified about all alpha-class injuries or illnesses** regardless of their severity.

First aid boxes must be checked and in place in the habitat prior to launch.

Consult **certified first aid specialist** in MC or HAB, if one is present, **before** any Alpha-class first aid procedures are taken.

**4.4.2 INJURY Procedure:** Apply first aid and reduce the astronaut's responsibilities as necessary.

**4.4.2.1 Puncture Wounds:** Clean the wound and bandage it once it has stopped bleeding.

**4.4.2.2 Skin Irritation:** Locate and remove the cause of the irritation. Rinse the affected area with cool water.

**4.4.2.3 Sprains, Strains and Bruises:** Apply ice and elevate the injury if possible. Try to avoid using sprained limbs.

**4.4.2.4 Heat Exhaustion:** Heat exhaustion is caused by exercise or work in a hot environment and may be recognized by the following symptoms: slightly elevated body temperature - cool, moist, pale or red skin; headaches; nausea; and dizziness, weakness, or exhaustion. Tell Mission Control immediately. Have the casualty rest in a cool place. Give him or her cooled water and apply cool, wet cloths to their skin. Loosen any tight clothing and remove perspiration-soaked clothes.

**4.4.2.5 Heat Stroke:** If heat exhaustion is not treated immediately, it may develop into heat stroke which is much more severe. Heat stroke can be recognized by high body temperatures, often as high as 41 °C (106 °F); red, hot, dry skin; irritable, bizarre, or combative behaviour; a progressive loss of consciousness; a rapid, weak pulse becoming irregular; and rapid shallow breathing. The treatment is the same as for heat exhaustion.

##### **4.4.3 ILLNESS Procedure:**

**4.4.3.1 Non Serious Illness:** Treat the symptoms in consultation with Mission Control. In general, the astronaut should rest, be kept warm, and be kept fed and hydrated. Febrile (fever) crew should be kept covered unless fever becomes too high. Keep febrile crew hydrated with gatorade, but do not permit the crew member eat until temperature returns to normal.

**4.4.3.2 Contagious Illness:** At the time a contagious illness is discovered, it is highly probable that all the astronauts have already been infected. Nonetheless, attempt to slow the spread of the disease by isolating the patient as much as possible. Use quarantine procedure P2.5.6. Use the Hotlab as the isolation chamber if the decontamination field is working.

**4.4.3.3 Class 4 Life-threatening Illness/Injury:** If an astronaut is exhibiting life-threatening illness, they must be evacuated. An Alpha-class mission abort (P4.6.2) may be initialized. In some cases, if the situation allows, procedure 4.4.4 may be followed.

**4.4.4 Class 3 Serious Illness/Injury:** The astronaut is to be placed in the emergency evacuation module. These devices are small and tubular. From inside the airlock, the astronaut enters the evacuation module which will arrive from below the Habitat. It will then fly and dock directly with the AYSE drive, where it will use a simplified form of the SLINCE drive to accelerate towards Earth. A coil in Earth orbit will catch the probe, and it will land just outside Mission Control. EMS should be called so that it arrives in time for the probe landing. The last time an emergency evacuation probe was used was the liquid-nitrogen falling on the foot incident. This occurred sometime before 1996. "Space Sim archives."

#### **4.5 HABITAT CONTAMINANT CONTROL**

**4.5.1 Contaminant General:** A contaminant is anything degrading the quality of the environment of the Habitat. Usually it is in the form of dangerous chemicals, air-borne or liquid. In all cases, avoid direct contact with the contaminant. The Module containing the contaminant should be sealed Evacuated and Sealed P4.21. Mission Control is to run analysis of the situation and locate the source of the problem. Astronauts should expect an IVA request from Mission Control.

**4.5.2 Liquid Contaminant:** The Astronauts should suit up for an IVA once cleared by Mission Control All other astronauts should exit to a module not adjacent to the contaminated modules). They are to seal themselves in said other module. The astronauts in IVAs are then to open the contaminated module. If realistic, a sample of the contaminant should be taken for later study. The Astronauts should then clean the spill and rectify the situation as directed by Mission Control.

**4.5.3 Gaseous Contaminant:** If there is a gaseous contaminant, the affected module(s) are to be vented by the Astronauts through the control panel. Once all traces of the contaminant are out of the air and Mission Control confirms, the astronauts are to then re-pressurize the module. If the astronauts cannot reach the Control Panel, Mission Control may assume these tasks. Before entering a module just cleaned, five minutes should be taken to assure that the gaseous contaminant does not return. If it does, an IVA may be needed to fix the source before venting can commence. If there is a liquid contaminant that is producing the gaseous contaminant, IVA suits will be needed clean the Liquid Contaminant P4.52 first.

#### **4.6 HABITAT MISSION ABORT**

**4.6.1 General:** If a Mission Abort is declared, the Astronauts must verify this with a code word hidden in the Habitat. The Mission Commanders will know the code word ahead of time, and they may also be used to confirm the word. The type of Abort must also be specified.

**4.6.2 Alpha Mission Abort:** If an Alpha Abort is declared, the astronauts can leave the Habitat and walk to Mission Control or out the back door following posted fire escape routes.

**4.6.3 Beta Mission Abort:** If a Beta Abort is declared, the Astronauts must immediately Launch off the planet, dock with the AYSE Drive, and return to Earth in the most speedy fashion possible. Mission Control must continue to monitor their progress and prepare a shuttle launch to rendezvous with them when applicable.

#### **4.7 BREAKER PANEL OPERATION**

**4.7.1 GENERAL:** Consult with a Tech Specialist or Tech Director for guidance. When restoring power, turn off all electronics and major electrical devices.

**4.7.2 RESTORING POWER (single module):** Shut down all affected electronics. Check the habitat GFCI breaker for the affected module. Press the black trip button then the red reset button. If the habitat GFCI breaker does not trip but the power does not come back on, attempt to determine and remove the cause of the overload. This may include excessive amount of operative electrical devices on one circuit. Contact MC for remote restoration of power at the main breakers.

**4.7.3 RESTORING POWER (entire habitat):** If the GFCI breakers have not been tripped, follow P4.2.3 (Beta Isolation) and inform Mission Control of the situation. Mission Control will inform you as to the nature of the emergency and might order P4.3.2 (Alpha Extreme Hazard Evac).

**4.7.4 TERMINATING POWER:** If the situation permits, shut down all electronics in the module(s) to be powered down. Then trip the GFCI breaker using the black button.

**4.7.5 REPETATIVE BREAKER TRIPPING:** The circuit is overloaded or potentially damaged. Terminate power to the circuit and remove (unplug) all electronics from the circuit. Follow P4.7.2 and wait. If the breaker trips again, the module is to be sealed for the remainder of the mission. Mission Control may order P4.3.1(General Alpha Evac) at the discretion of the Commanders and Tech Director.

## **4.8 MUTINY & HIJACKING**

**4.8.1 MUTINY/Hijacking:** A person, or a group of people, take control of the Habitat. This may be Mutinying Astronauts or Hijackers. Mission Control is to immediately get in contact with the hijackers/mutineer. They must negotiate with these people. Supply their demands: you must get the Mission Commander and the Habitat back to Earth in one piece.

**4.8.2 Mutiny:** Try to convince them to stand down. You may have to threaten the mutineers. If the Mission Commander is dead, or segregated, offer to lower oxygen levels in their module. Attempt to gain complete remote control of the Habitat. Seal off the interlock. Offer to inject radiation into the Habitat. Once returned to Earth, the mutineers are to be taken into custody regardless of what occurs. If absolutely necessary, detonate the Habitat (P4.84)

**4.8.3 Hijacking:** If another party boards the Habitat, and you cannot negotiate with them. Mission Control is to aid the Astronaut remotely to retake the Habitat by force, if viable. Seal off the Interlock. Gain complete remote control of the Hab. Attempt to vent or depressurize modules with hijackers, if it doesn't affect the astronauts. If in space, deactivate the 3DMI to remove artificial gravity. If the astronauts are dead, follow P4.84.

**4.8.4 Habitat Self-Destruction:** If there is no way to return the Habitat and/or the Mission Commander and loyal astronauts are dead, activate the self-destruct circuit. Only the Mission Commander on Earth will know the activation code. The MC mission commander activates the destruct function by pressing F1 on the ORBIT50t software at the GUIDO station and type in the destruct code. The code is processed by the Habitat and AYSE drive control systems which shut down the reactor plasma containment systems. Once the containment systems are shut down, the containment field will deteriorate and fail in approximately one minute. When the field fails, the AYSE drive module and Habitat will detonate.

## **4.9 INSTRUMENTATION**

### **4.9.1: Instrumentation failure, replacement, and general problems**

**4.9.2 Instrumentation Failure:** If an instrument is broken or not reading correctly, run diagnostics upon it. If it is software or control panel, consult with Mission Control, the Mission Commander, or someone knowledgeable in the computer system about how to repair. Generally speaking, someone in MC should know how to replace any broken instrument, and they will all have their own replacement procedure. This will be covered during Astronaut/Flight Team Training each year.

**4.9.3 Instrument Replacement:** If an instrument cannot be repaired, it should be replaced. Find the spare in the Emergency Repair Kit, and attach it where needed in the same form that the original was attached. Consult Mission Control and your Astronaut or Flight Team Training for replacement of parts.

## **5.0 DISCREPANCY PROCEDURES**

### **5.1 ASTRONAUT REPORTS HAZARD**

**5.1.1 In Contradiction to Instruments:** When an astronaut reports a hazard in contradiction to instruments, believe the astronaut. Proceed to react according to reported hazard. After the reported hazard has been remedied, proceed with the instrument re-calibration.

**5.1.2 In Contradiction to Video Feed:** When an astronaut reports a hazard in contradiction to video feed believe the astronaut. Proceed to evacuate astronauts from the hazard location. Attempt to verify hazard on video feed. If you can identify the hazard on video, proceed as normal. If you cannot identify the hazard on video follow P5.11 with the exceptions that follow.

When the astronauts go on repair EVA, ensure that the EVAs locate the hazard for Mission Control visually on camera. If Mission Control can identify the hazard on camera, treat the situation as a standard repair EVA with no follow up. If Mission Control cannot identify the hazard on camera, treat the situation as a standard repair EVA. but follow up with a camera check. In both cases, no instrument re-calibration should be necessary.

**5.1.3 In Contradiction to Mission Control Staff:** When an astronaut reports a hazard in contradiction to Mission Control Staff, verify that this is not another situation. If it is 5.1.3, believe the astronaut. Proceed to react according to the reported hazard. After the hazard has been remedied, explain to the Mission Control Staff that they are not in the habitat.

**5.1.4 In Contradiction to Another Astronaut:** When an astronaut reports a hazard in contradiction to another astronaut report, evacuate astronauts from the hazard situation. Immediately attempt to determine if this is another situation. If it is not, proceed as if the hazard is real unless the reporting astronaut changes their statement and indicates the reason for the change.

### **5.2 INSTRUMENT REPORTS HAZARD**

**5.2.1 In Contradiction to Astronaut:** When an instrument reports a hazard in contradiction to an astronaut opinion, believe the instrument, and evacuate the astronauts from the hazard situation. The first EVA should be a hazard location/instrument repair EVA. The EVA should first attempt to determine if a hazard exists which corresponds to the instrument reading. If no such hazard exists, the EVA should attempt to perform the instrument replacement procedure (pending) on any instruments that may be malfunctioning.

**5.2.2 In Contradiction to Another Instrument:** When an instrument reports a hazard in contradiction to another instrument, evacuate the astronauts from the hazard location, and send an investigative EVA to determine if a hazard exists. If no hazard exists, call instrument failure procedure (pending)

### **5.3 ORDERS ISSUED BY GOVERNMENT OR OCESS COMMAND**

**5.3.1 Flight Director's response:** The Flight Director must comply with orders issued by government or OCESS Command (teacher advisor or designate), once they have been confirmed between the Habitat Commander and Mission Control Commander by means of activation codewords. The Flight Director may issue orders that aid or do not hinder government's/Command's orders, but will be overridden at the discretion of the Habitat Commander when the orders conflict directly.

**5.3.2 Habitat Commander's response:** The Habitat Commander must confirm any orders issued by government/OCESS Command with the Mission Control Commander by means of an activation codeword written on the orders and known only to the Mission Control Commander. Should the Flight Director's orders directly conflict with the written orders, once confirmed, the Habitat Commander is entitled to override the Flight Director, only for the purpose of completing the orders. Authority reverts to the Flight Director once the orders are carried out or the orders are no longer in conflict.