Space Shuttle Vessel

SSV Operations Manual

Version 1.1

The dream is alive.

John Young - STS-1 Commander

PREFACE

Space Shuttle Vessel (SSV) is an addon for Orbiter Space Flight Simulator (http://orbit.medphys.ucl.ac.uk/). The purpose of this addon is to simulate NASA's Space Transportation System Program as much as possible. Currently only some elements have been completed and work on others is ongoing.

The basis for SSV was the Space Shuttle Ultra addon, and through corrections and performance improvements it delivers a better experience for users and more capabilities for mission simulation.

The latest version of SSV is available at the project homepage (https://github.com/GLS-SSV/SSV), and a thread for discussion exists in Orbiter-Forum (https://www.orbiter-forum.com/threads/space-shuttle-vessel.37856/).

Currently, SSV simulates a number of systems, displays, and procedures of the real shuttle and can be used along with real NASA Flight Data File (FDF) checklists to complete tasks. These checklists can be found at the NASA Flight Data Files web page (https://www.nasa.gov/centers/johnson/news/flightdatafiles/index.html), and provide a good reference for other procedures. The NASA Flight Data Files site includes checklists for all missions after STS-107, as well as generic checklists.

Other good NASA references are the Shuttle Crew Operations Manual (SCOM), the DPS Dictionary, and the various Workbooks and Handbooks that are available on the Internet (these can also be found at the above link).

This document contains the condensed material taken from various NASA documents as well and Orbiter Space Flight Simulator and SSV specific information. The goal of this document is to provide a typical Orbiter Space Flight Simulator user the information needed to perform basic SSV flights as well as to aid in basic custom mission creation, as well as provide information for developers who would like to create SSV-compatible payloads.

This document is formatted to look the same as the SCOM to facilitate changing from one document to the other. Additional information or clarification is presented in three formats: notes, cautions, and warnings. Notes provide amplifying information of a general nature. Cautions provide information and instructions necessary to prevent hardware damage or malfunction (not yet simulated). Warnings provide information and instructions necessary to ensure crew safety (also not simulated). The formats in which this material appears are illustrated below.

NOTE

A barberpole APU/HYD READY TO START talkback will not inhibit a start.

CAUTION

After an APU auto shutdown, the APU FUEL TK VLV switch must be taken to CLOSE prior to inhibiting auto shutdown logic. Failure to do so can allow the fuel tank isolation valves to reopen and flow fuel to an APU gas generator bed that is above the temperature limits for safe restart.

WARNING

The FUEL CELL REAC switches on panel R1 are in a vertical column with FUEL CELL 1 REAC on top, FUEL CELL 3 REAC in the middle, and FUEL CELL 2 REAC on the bottom. This was done to allow the schematic to be placed on the panel. Because the switches are not in numerical order, it is possible to inadvertently close the wrong fuel cell reactant valve when shutting down a fuel cell.

Contents

1 INSTALLATION INSTRUCTIONS

1.1 Installation

1. Install Orbiter.
2. Install the required addons:
   OrbiterSound 4.0 or 5.0 (`http://orbiter.dansteph.com/forum/index.php?page=download`)
   Antelope Valley scenery pack (`https://orbit.medphys.ucl.ac.uk/mirrors/orbiter_radio/tex_mirror.html`)
3. Extract the SSV files into your Orbiter installation folder, overwriting any existing files.

   WARNING

   The SSV installation overwrites the default Base.cfg and Earth.cfg files.

4. Install the "SSV_Font_A" and "SSV_Font_B" fonts, located in the "<Orbiter installation>\Install\Space Shuttle Vessel" directory, by opening them and selecting "Install". After successful installation the files can be deleted.
5. The displays in SSV require the MFD resolution of 512 x 512 (Orbiter Launchpad → Extra → Instruments and panels → MFD parameter configuration → MFD texture size).

NOTE

If you encounter the error "msvcp140.dll is missing" you need to download the Microsoft Visual C++ Redistributable for Visual Studio 2017.

1.2 Optional addons

For a better visual experience, using the D3D9 graphics client (`http://users.kymp.net/~p501474a/D3D9Client/`) is strongly recommended, although not required (minimum version R4.25). If using the D3D9 graphics client, the *Disable near clip plane compatibility mode* option in the D3D9 Advanced Setup dialog (Orbiter Launchpad → Video → Advanced) should be checked.

For an accurate rendezvous profile simulation, it is recommended the installation of the excellent Shuttle FDO MFD (`https://github.com/indy91/Shuttle-FDO-MFD`) by indy91, which handles the ground based calculations required for rendezvous.

2 SPACE SHUTTLE OVERVIEW

Contents

A small overview of the Space Shuttle is provided in this chapter. Further detail is available in the SCOM.

2.1 Description

The Space Shuttle is a reusable space transportation system designed to launch and return payloads from Low Earth Orbit (LEO).
The main component is the Orbiter Vehicle (OV), which contains the major systems, crew and payload. For launch, the OV is attached to the External Tank (ET) which feeds the propellant to the 3 Space Shuttle Main Engines (SSME) in the OV. For further thrust during launch, 2 Solid Rocket Boosters (SRB) are attached to the ET.

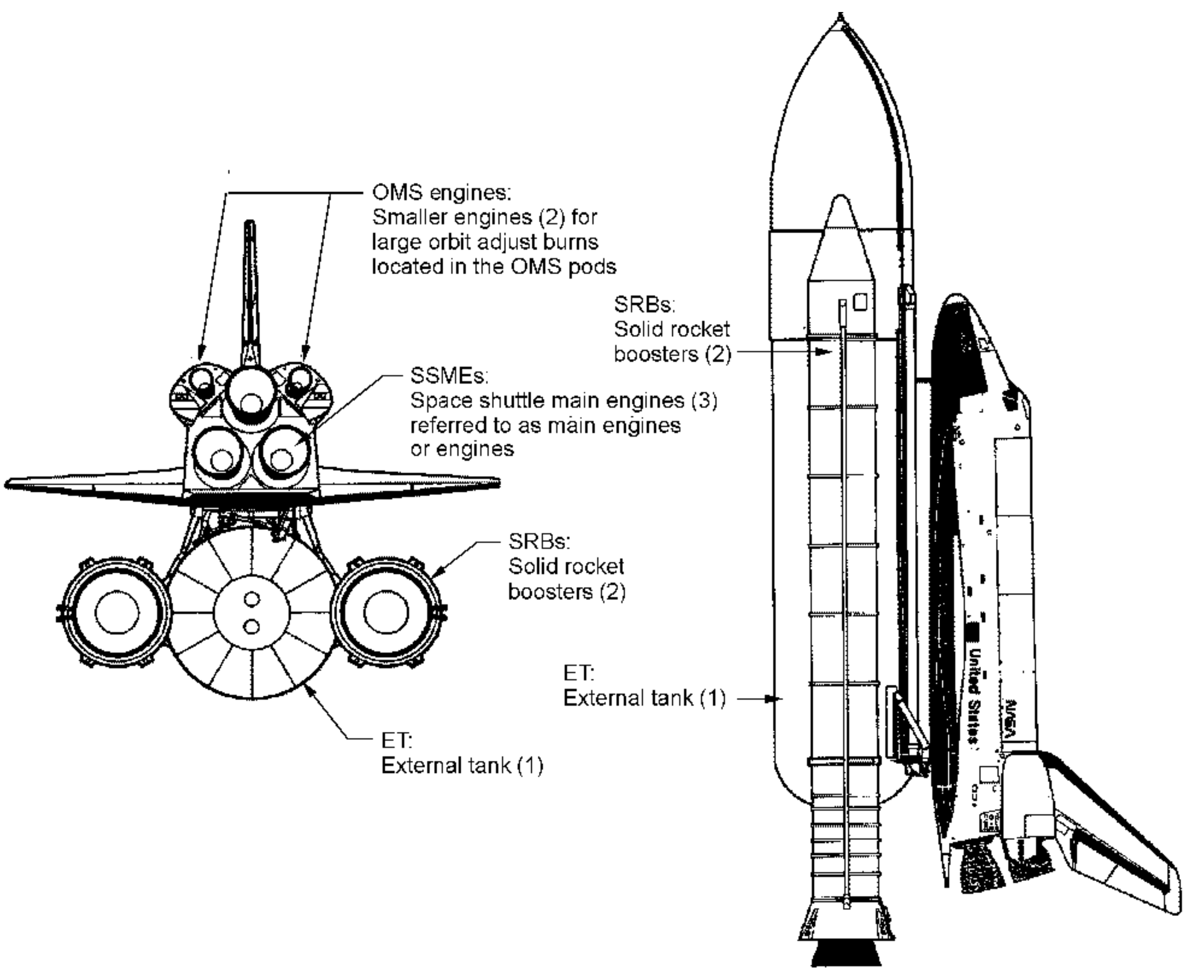


Figure 1: Space Shuttle

2.2 Nominal Mission Profile

Launch

The launch is designed to guide the vehicle from the launch pad all to way to a pre-defined orbit. The SSMEs and SRBs are ignited on the pad, and fire together for about 2 minutes until the SRBs burnout and separate, ending what is know as "first stage". For the final 6 minutes of powered flight, called "second stage", the 3 SSMEs continue firing until the target velocity, and other parameters, are achieved. That point is called main engine cutoff (MECO). Shortly after MECO, the ET is separated, leaving the OV to fly the rest of the mission alone.
Although after MECO the OV is in space, it is a sub-orbital trajectory, and Orbital Maneuvering System (OMS) burns are required to finalize orbit insertion. The OMS-1 burn, about 2 minutes after MECO, is the first of the 2 orbit insertion burns, and it raises the apogee. The OMS-2 burn, about 45 minutes after launch at the apogee, raises the perigee. To increase payload mass, a "Direct Insertion" was developed, as opposed to the "Standard Insertion" described above, where MECO places the OV in an orbit such that the OMS-1 burn is not required.

Orbit

After MECO, OV attitude control and small orbit changes are provided by the Reaction Control System (RCS), while large orbit changes are performed by the OMS. The payload bay doors (PLBD) are opened early in the mission, so the radiators inside can cool the vehicle systems, while also allowing the payload operations to be performed. Mission objectives might call for a satellite deployment or retrieval, rendezvous and docking with a space station, scientific research in a pressurized module inside the PLB, or a combination of the above. At the end of the mission, the PLBDs are closed for entry, and the OMS are used for a final burn to slow the vehicle down for entry into the atmosphere.

Entry

Entry and landing are the final phases of the flight, guiding the OV from Entry Interface (EI) at 400k ft (121.92 km) all the way to an unpowered landing on a pre-selected runway. During the early phases of Entry, the vehicle is controlled by the RCS, but as the vehicle descends and the atmosphere gets more dense, the aerosurfaces begin to take over, and the usage of the RCS is eventually terminated.
The final approach to the runway is usually controlled by the Commander, which lands the vehicle and brakes to a stop. A drag chute was added to the OVs to help slowing down, thus decreasing loads on the brakes.
After the vehicle stops on the runway, a ground convoy approaches and work to turnaround the vehicle for another mission begins.

2.3 Orbiter Vehicle (OV)

The Orbiter Vehicle (OV) is the main part of the Space Shuttle.

The crew module, located in the forward fuselage, provides living space for up to 10 crew members, along with displays and controls for them to perform the mission. The aft compartment contains the SSMEs and associated MPS equipment. On-orbit attitude control is provided by the RCS, while aerosurfaces in the back of the wings and tail provide control in atmospheric flight. Orbit change maneuvers are performed with the OMS engines, located on top of the aft compartment.
For protection during entry, the entire OV is covered with fragile tiles and blankets, which make up the Thermal Protection System (TPS).
The OV has a 15x60 ft (4.572 x 18.288 m) Payload Bay (PLB), which was designed to carry up to 65k lbs (29483.5 kg) of payload into orbit, and return 32k lbs (14514.96 kg) to Earth. Actual performance varied between OVs, as well as during the lifetime of the program.
For payload deploy and/or retrieval operations, the Remote Manipulator System (RMS) arm can be carried in the PLB. Post-Columbia accident flights carried the Orbiter Boom Sensor System (OBSS), which allows inspection of the TPS.
A total of 5 space-worthy OVs were build: OV-102 (Columbia), OV-099 (Challenger), OV-103 (Discovery), OV-104 (Atlantis) and OV-105 (Endeavour).

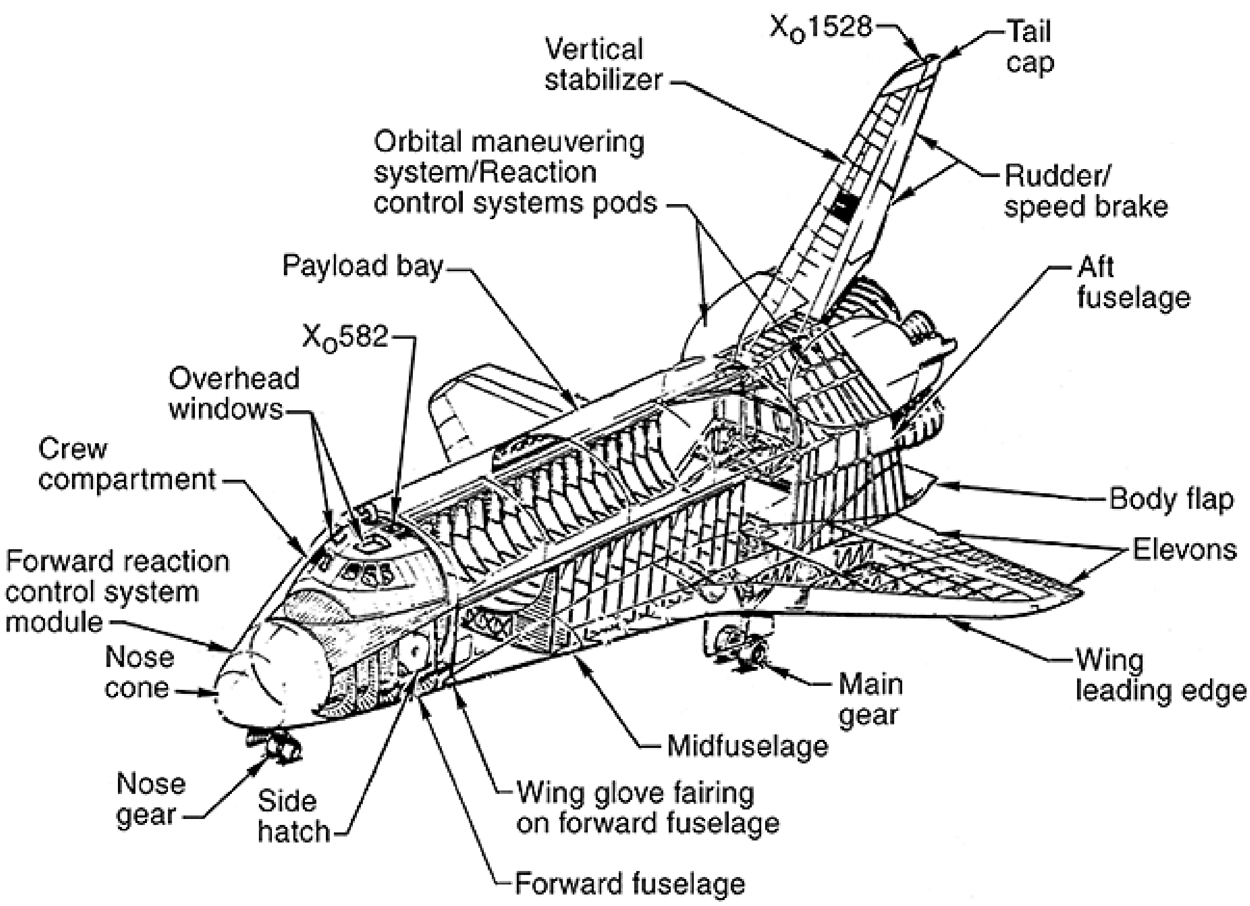


Figure 2: Orbiter Vehicle

2.3.1 Coordinate System

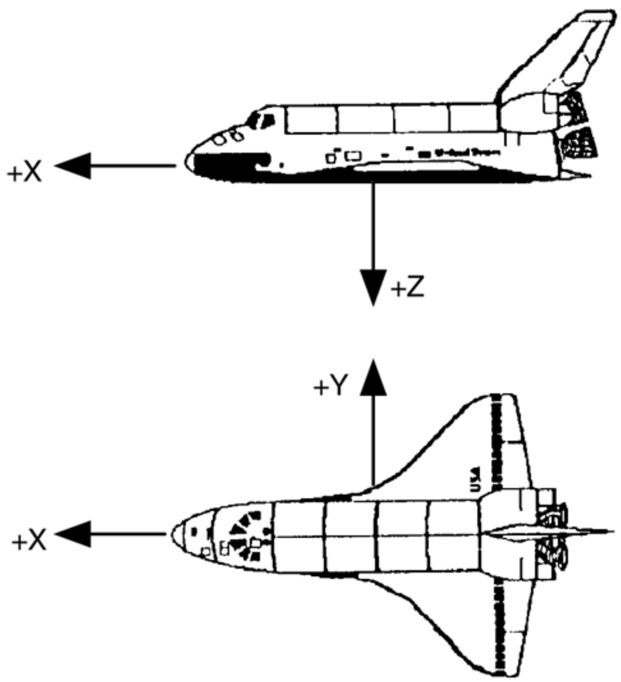


Figure 3: Body Axis Coordinate System

Figure 3 shows the shuttle Body Axis Coordinate system.
It should be noted that the Body Axis Coordinate frame is different from the normal Orbiter Space Flight Simulator frame.

2.3.2 Main Propulsion System (MPS)

The Main Propulsion System (MPS) is composed of the 3 SSMEs, that provide thrust during the whole launch, and propellant manifolds to feed propellants to the engines from their tanks in the ET.

Space Shuttle Main Engines (SSME)

The SSMEs are high performance liquid propellant rocket engines located in the aft compartment of the orbiter. They can operate between 65% and 109% of their rated thrust, 370k lbf (1.646 MN), and are throttled down temporarily early in the ascent to reduce aerodynamic loads on the vehicle, and then again late in the ascent to keep the acceleration under 3g.

MPS Dump

Following MECO and ET separation, the MPS Dump is automatically started to vent remaining MPS propellants from the engines and the manifolds. Liquid oxygen is vented thru the SSMEs and the liquid hydrogen is vented thru the backup LH2 dump valves and the LH2 fill and drain valves located on the port side of the OV.

2.3.3 Auxiliary Power Unit/Hydraulics (APU/HYD)

The OV has three independent hydraulic systems, each powered by an Auxiliary Power Unit (APU). Each system provides hydraulic pressure during launch and entry to control the SSMEs, the aerosurfaces, brakes and nose-wheel steering.
The APUs are started 5 minutes before launch and shut down shortly after MECO. The day before entry, a single APU is started for the FCS checkout. A single APU is started 5 minutes before the deorbit burn (this is done to ensure at least 1 APU is functioning before committing to entry). The remaining APUs are started 13 minutes before Entry Interface. All 3 APUs are shut down after landing.

2.3.4 Orbital Maneuvering System (OMS)

The Orbital Maneuvering System (OMS) is contained in 2 pods, located on the aft of the OV, each containing propellant tanks and an engine for large translation maneuvers in orbit. The OMS engines can be fired together or individually.

2.3.5 Reaction Control System (RCS)

The OV has 44 Reaction Control System (RCS) jets that provide for attitude control during the orbit and early entry phases of the flight, as well as small translation maneuvers in orbit.
The thrusters and associated propellant tanks are located in the nose of the OV and in the aft end of the OMS pods.

2.3.6 Aerosurfaces

The aerosurfaces allow control of the OV during atmospheric flight. They consist of 4 elevons, 2 on each wing, which provide pitch and roll control; a body flap in the aft compartment for elevon trim; a rudder in the vertical tail, made up of 2 panels, for turn coordination; and a speed brake, which opens the 2 rudder panels to create drag, allowing for energy control during the final approach to the runway.
Their movement is controlled with hydraulic actuators, powered by the 3 hydraulic systems.

2.3.7 Payload Deploy and Retrieval System (PDRS)

The Payload Deploy and Retrieval System consists of payload retention latches that hold large payloads inside the PLB, and the Remote Manipulator System (RMS) which allows for payload deploy and retrieval.

Remote Manipulator System (RMS)

To deploy and retrieve payloads from the PLB the OV has a Canadian-built robotic arm know as the Remote Manipulator System (RMS). It has 6 joints allowing motion similar to the human arm. The End Effector (EE), located at the tip of the RMS, allows it to grapple payloads. The RMS can be moved in a single-joint mode, or moved along the axes of the OV or of the End Effector, thus allowing flexibility in its operation.
The RMS is positioned on the port side of the Payload Bay, mounted on the Manipulator Positioning Mechanism (MPM) that must be rolled out prior to RMS usage.

2.3.8 Extra Vehicular Activities and Docking Operations Overview

Extra Vehicular Activity (EVA), or spacewalk, is used on some missions for work outside the shuttle, either for retrieving a satellite or most recently, for the assembly of the ISS. Independently of mission tasks, all missions have contingency EVA capability for manual payload bay door closure. EVA requires the use of an airlock, which on the shuttle can be located inside the middeck (Internal Airlock), or outside on the payload bay (External Airlock). EVA is currently not supported by SSV.
For missions requiring docking with the ISS or Mir, the orbiter need to be fitted with the Orbiter Docking System (ODS). The ODS is mounted on top of the External Airlock, and is controlled from panel A7L, allowing ODS powerup and docking ring extension and retraction.

WARNING

A future version of SSV will introduce changes to the docking port format. In addition to the docking port, there must exist an child attachment, in the same location, with the id "APAS" to achieve soft-docking. Without the attachment, docking will not be possible.

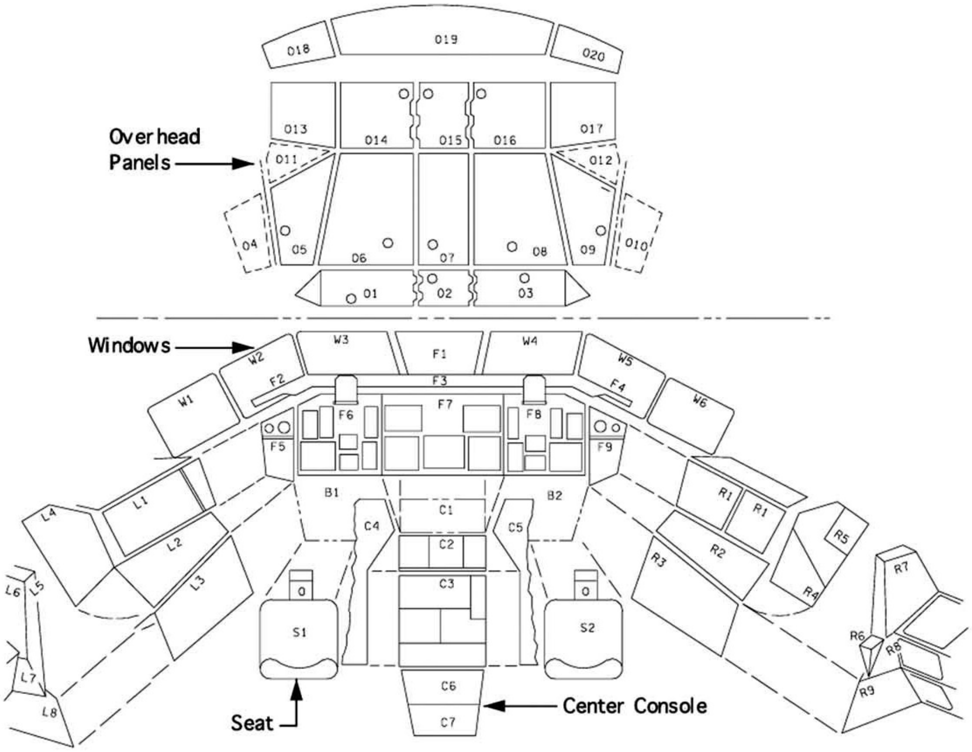
For missions requiring the ODS to be located aft of its normal position (e.g. STS-88), the Tunnel Adapter Assembly (TAA) is positioned between the External Airlock and the forward bulkhead, effectively acting as a spacer. The TAA must also be used on missions carrying the Spacelab or the SpaceHAB modules. It must be placed at the forward end of the tunnel to provide a way in/out of the airlock during an EVA.

2.3.9 Crew Compartment Location Codes

Crew Compartment location codes enable crew members to locate displays and controls, stowage compartments and lockers, access panels, and wall-mounted equipment in the OV crew compartments. The crew compartments are the flight deck, middeck, and airlock. Because of compartment functions and geometry, each has a unique location coding format.
A flight deck location code consists of two or three alphanumeric characters. The first character is the first letter of a flight deck surface as addressed while sitting in the commander/pilot seats. The second and third characters are numbers identifying the relative location of components on each flight deck surface. Table 1 lists the surfaces and the numbering philosophy for each surface. Figures 4 and 5 show the flight deck panels and their location codes.

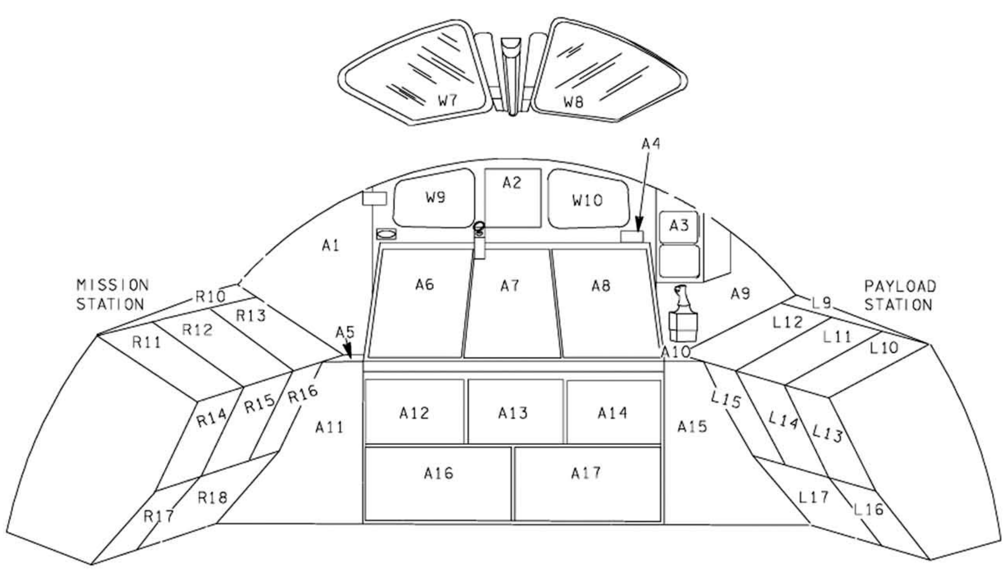
SURFACES	NUMBERING PHILOSOPHY
L - Left R - Right C - Center Console	Numbered from top to bottom, forward to aft
O - Overhead	Numbered from left to right, forward to aft
F - Forward A - Aft	Numbered left to right, top to bottom (facing the surface)
W - Windows	**Forward** (W1 through W6): numbered left to right facing forward **Overhead** (W7 & W8): numbered left to right facing aft **Aft** (W9 & W10): numbered left to right facing aft
S - Seats	CDR seat is S1, PLT seat is S2, S3 and S4 are also in the flight deck, the rest in the middeck

Table 1: Flight Deck Numbering scheme



Flight Deck Location Codes (1 of 2)

Figure 4

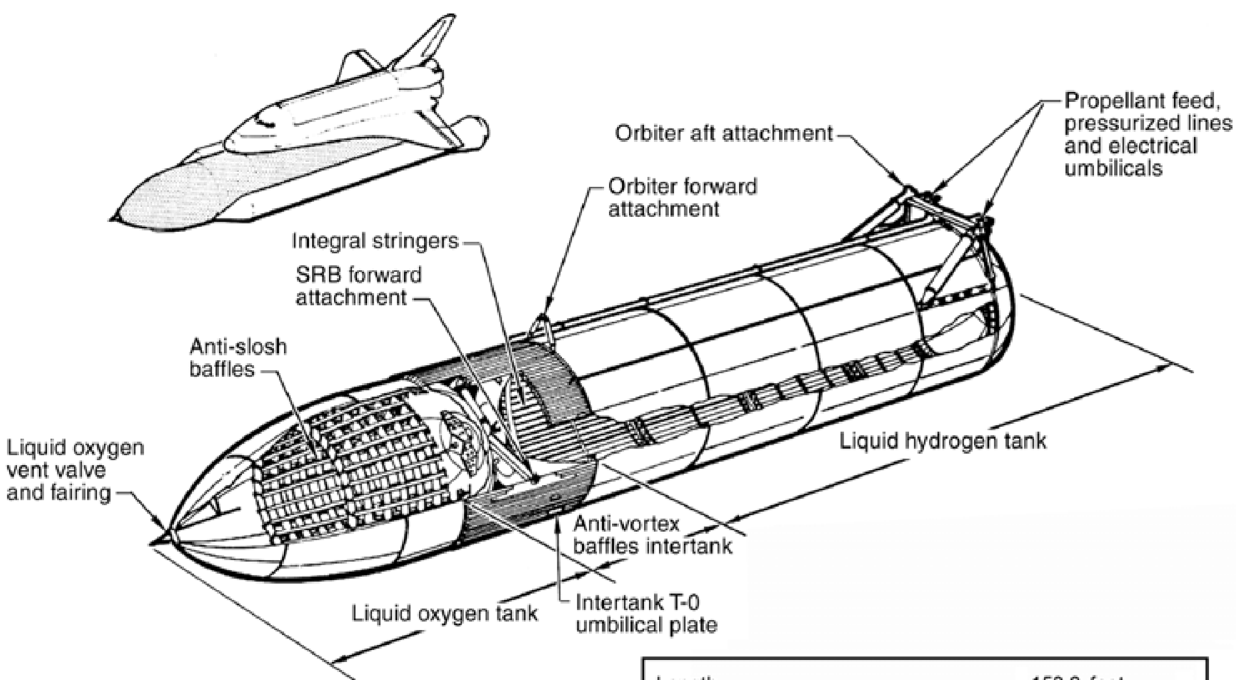


Flight Deck Location Codes (2 of 2)

Figure 5

2.4 External Tank (ET)

The External Tank (ET) holds the liquid hydrogen and liquid oxygen propellants for the Main Propulsion System, and serves as a backbone for the whole Space Shuttle vehicle during launch. It separates from the OV about 8 minutes and 30 seconds after launch. The ET is the only major component of the Space Shuttle that is not reusable, and burns up in the atmosphere following launch. To keep the cryogenic propellants from boiling, the ET is covered in spray-on foam insulation.
A total of 3 versions of the ET were build:
⇒ Standard Weight Tank (SWT), the original design of the ET. For the first 2 flights it was painted with Fire Retardant Latex (FRL) paint, giving it a white color;
⇒ Light Weight Tank (LWT), a lighter weight ET resulting from structural changes;
⇒ Super Light Weight Tank (SLWT), further weight reductions to improve payload capability.



Length	153.8	feet
Diameter	27.6	feet
Average gross lift-off weight (SLWT)	1,658,217	pounds
Inert weight (SLWT)	58,500	pounds
Liquid oxygen maximum	1,376,240	pounds
	144,857	gallons
Liquid hydrogen maximum	230,302	gallons
	389,770	gallons
Average total LO2/H2	532,776	gallons
Burn rate (104%)	64,957	gallons/min
	1,083	gallons/sec
(all weights/rates are approximate)		

Figure 6: External Tank

2.5 Solid Rocket Boosters (SRB)

The Solid Rocket Boosters (SRB) are solid propellant rockets that provide the majority of the thrust during the early phases of the launch, separating when their propellant is exhausted at about 2 minutes after launch. Following separation, they parachute down to the ocean not far from the launch site, are recovered and refurbished for another launch.
The main component of the SRB is the Solid Rocket Motor (SRM), a 4-segment solid-propellant rocket.
There are 4 types of SRMs:
⇒ Standard Performance Motor (SPM), the original SRM;
⇒ High Performance Motor (HPM), a lower-mass and higher-thrust upgrade to the SPM;
⇒ Filament Wound Case (FWC), a lighter, composite case SRM planned to be used from SLC-6;
⇒ Redesigned Solid Rocket Motor (RSRM), developed in response to the Challenger accident.

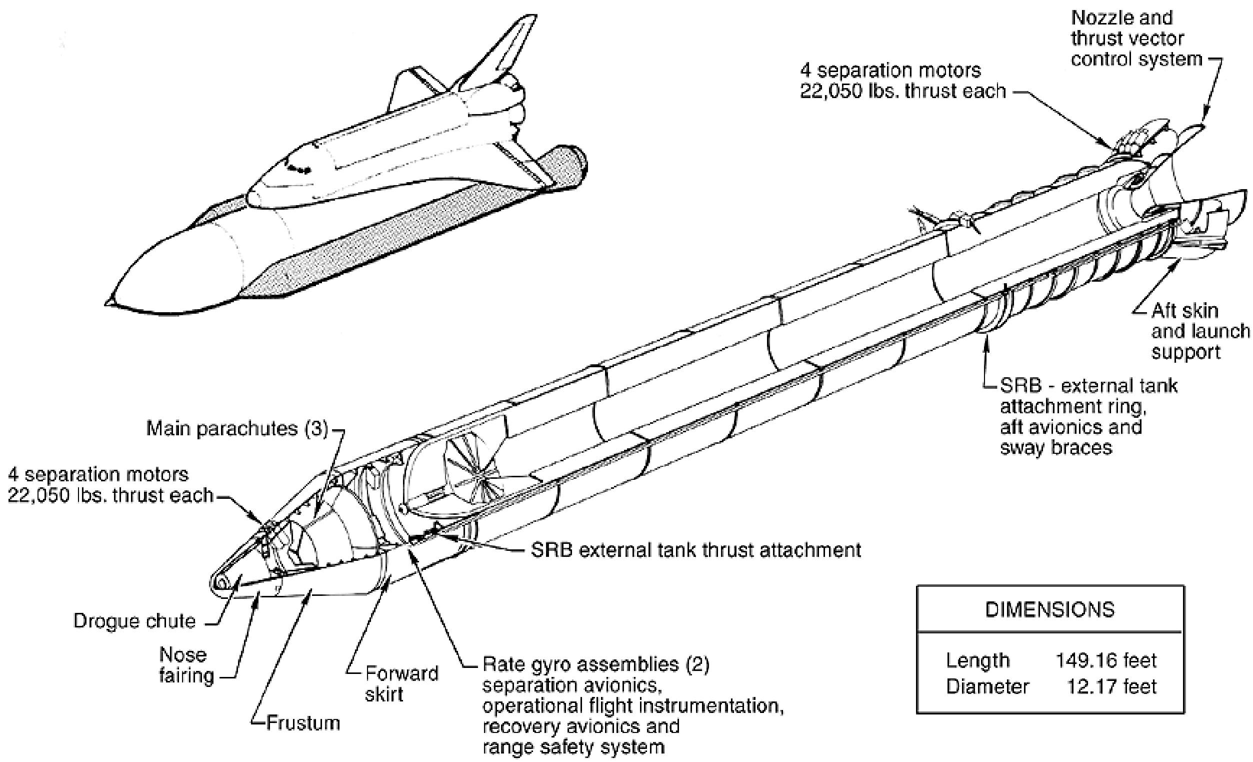


Figure 7: Solid Rocket Booster

3 SSV and Orbiter Space Flight Simulator

Contents

The section provides information about how to operate Space Shuttle Vessel in Orbiter Space Flight Simulator.

3.1 SSV Keyboard Commands

The ultimate goal of SSV is to provide a complete simulation of the Space Shuttle. This means that most of the input is done with in-simulation controls (i.e. cockpit switches, GPC keyboards, and dialog windows). This results in very few keyboard commands to operate the shuttle.

General

Ctrl+A - toggle between CDR/PLT/AFD RHC and THC, and RMS RHC and THC
Ctrl+G - arm landing gear
G - deploy landing gear

RMS

Ctrl+Enter - grapple
Ctrl+Backspace - release
Ctrl+O - toggle between Coarse and Vernier rates

3.2 Rotational Hand Controller / Translational Hand Controller

The regular Orbiter Space Flight Simulator thruster control commands (either keyboard or joystick) are used to simulate the Rotational Hand Controller (RHC) & Translational Hand Controller (THC). To use the RHC and THC, the associated *FLT CNTLR PWR* switch must be on, as well as the associated (Display Driver Unit) DDU. For the RMS RHC and THC, the RMS needs to be powered.

The RHCs on the real shuttle have a "soft stop" and a "hard stop" (the mechanical limit of movement). Moving the RHC out of detent (up to the soft stop) will command either a constant rotation rate or a pulse of RCS firings to change the rotation rate by a specified amount (depending on whether *DISC RATE* or *PULSE* has been selected). Moving the RHC past the soft stop will result in continuous thruster firings in the appropriate axis. In SSV, a thruster command of <75% is considered to be within the soft stop; a thruster command of >75% is treated as RHC deflection beyond the soft stop. When using keyboard controls, the normal keyboard controls are equivalent to full RHC deflection, while holding down the Ctrl key is equivalent to deflection within the soft stop. The THC (and the RMS controls) does not have this idea of a soft stop. When *NORM* is selected in a translational axis, the thrusters will fire continuously if the THC is moved out of detent. When *PULSE* is selected, the thrusters will fire to provide a specified ΔV (the TRAN PLS rate specified on the SPEC 20 DAP CONFIG display). When controlling the RMS, the commanded rotation/translation rates are always directly proportional to the RHC/THC deflection. RHC trim switches are commanded with the Shift+Arrow Key.

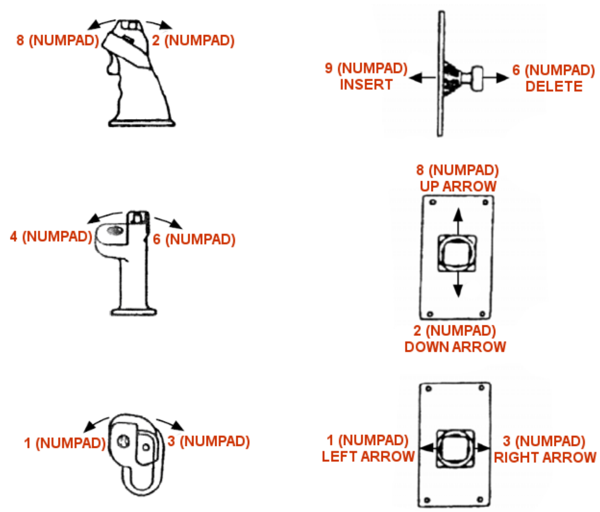


Figure 8: RHC/THC key mapping

3.3 Speedbrake/Thrust Controller

The Speedbrake/Thrust Controller (SBTC) controls both SSME throttling during ascent and the speedbrake setting during entry. In Orbiter, the SBTC is controlled in 5% intervals, in the forward direction by the numpad *Subtract* key, and in the aft direction via the numpad *Add* key. The takeover switch, used to initiate manual control of the SSME throttle or speedbrake settings, is simulated by the *Minus* key. The appropriate *FLT CNTLR PWR* switch must be on, as well as the appropriate DDU, for the SBTC to be active. Each SBTC is animated so the user can tell what setting is being commanded. During ascent, a full aft SBTC position corresponds to MPL (Minimum Power Level), usually 65 or 67% SSME throttle; full forward SBTC position corresponds to the current maximum SSME throttle, a value ranging from 100 to 109%, depending on mission or abort case. During landing, full aft SBTC position corresponds to the speedbrake being **fully open**; full forward SBTC position corresponds to the speedbrake being commanded **fully closed**.

Ascent

During ascent, SSME throttling is usually controlled by autopilot; in this case, the *AUTO* portion of the *SPD BK/THROT* PBIs on Panel F2 & Panel F4 is lit, and **THRTL: Auto** is displayed in the A/E PFD display. To takeover manual control of the SSME throttle command, press the SBTC takeover switch and move the SBTC to match the current SSME auto command (displayed in the Ascent Traj displays). When the SBTC takeover switch is pressed both *AUTO* PBIs will go out, indicating a manual takeover is in progress, but not completed. When the SBTC-commanded SSME throttle setting matches the auto command within 4%, the PLT *SPD BK/THROT MAN* PBI will be lit and **THRTL: Man** appears in the A/E PFD display, indicating that the SSME throttle is now under manual control. To return to auto SSME throttle control, press either *SPD BK/THROT MAN* PBI. A manual MECO can be commanded by pressing the NUMPAD * key (in real life, this is done by simultaneously pressing all 3 *MAIN ENGINE SHUT DOWN* push buttons on Panel C3; this is not possible in Orbiter).

Entry

The speedbrake is usually controlled automatically throughout entry, with the *AUTO* portion of the *SPD BK/THROT* PBIs on Panel F2 & Panel F4 is lit, and **SB: Auto** is displayed in the A/E PFD display. To take over manual control of the speedbrake press the SBTC takeover switch; the speedbrake will immediately move to the position commanded by the SBTC, the *AUTO* portion of the *SPD BK/THROT* PBIs will go out and the *MAN* PBI will be lit on either the CDR or PLT position (depending on what SBTC takeover switch was last pressed). Pressing the either *SPD BK/THROT* PBI, will put the speedbrake into *AUTO* mode again.

3.3.1 Rudder Pedal Transducer Assembly

The Rudder Pedal Transducer Assembly (RPTA) allows manual control of the rudder during the later part of reentry, as well as the Nose Wheel Steering during rollout. The RPTA also contains the brake pedals, which in addition to braking provide another means of lateral control during rollout. Although the rudder is automatically controlled, manual control is available when the R/Y channel is in CSS. The appropriate *FLT CNTLR PWR* switch must be on, as well as the appropriate DDU, for the RPTA to be active.

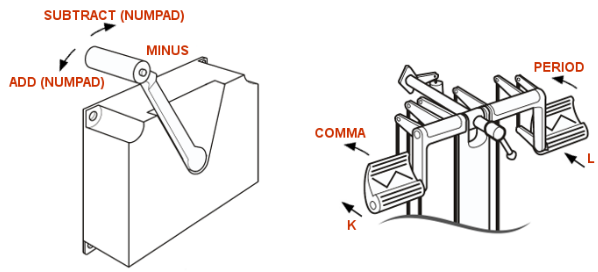


Figure 9: SBTC/RPTA key mapping

3.4 Camera Views

SSV includes the four payload bay cameras, the 2 RMS cameras and the Orbiter Docking System (ODS) centerline camera. The PLB and Elbow RMS cameras are controlled from panel A7U on the flight deck. In the PLB and RMS camera VC views, the cameras can also be controlled using Alt+Arrow keys.

3.5 Navigating the Virtual Cockpit

SSV has several Virtual Cockpit (VC) positions, allowing the user to navigate between the main locations and station of the crew module. Table 2 lists all the available VC positions, as well as neighbour positions accessed with the standard Ctrl+Arrow key combination. Each position also has lean positions (Alt Gr+Arrow key) which allow better positioning to reach a specific panel or window.
For assistance in navigating the VC, the name of the position is shown for a few seconds at the top of the screen during the simulation.

Cockpit View	Left	Right	Up	Down
Commander Seat	CDR - L4	Pilot Seat	PLB Camera A *or* ODS Camera[c]	MS Seat
Pilot Seat	Commander Seat	Pilot - R4	PLB Camera D *or* ODS Camera[c]	MS2/FE Seat
CDR - L4	Port Workstation	Commander Seat	PLB Camera D *or* ODS Camera[c]	MS Seat
Pilot - R4	Pilot Seat	Stbd Work Station	PLB Camera D *or* ODS Camera[c]	MS2/FE Seat
MS Seat	Port Workstation	MS2/FE Seat	Commander Seat	PLB Camera A *or* ODS Camera[c]
MS2/FE Seat	MS Seat	Stbd Work Station	Pilot Seat	PLB Camera A *or* ODS Camera[c]
Port Work Station	RMS Work Station	Commander Seat	PLB Camera A *or* ODS Camera[c]	Mid Deck
Stbd Work Station	Pilot Seat	Aft Pilot Station	PLB Camera D *or* ODS Camera[c]	Aft Work Station
Aft Work Station	Stbd Work Station	Port Workstation	RMS Work Station	MS Seat
Aft Pilot Station	Stbd Work Station	RMS Work Station	PLB Camera D *or* ODS Camera[c]	Aft Work Station
RMS Work Station	Aft Pilot Station	Port Work Station	PLB Camera A *or* ODS Camera[c]	Aft Work Station
RMS EE[a]	RMS Elbow	-	-	RMS Work Station
RMS Elbow[a]	-	RMS EE	-	RMS Work Station
PLB Camera A	PLB Camera D	PLB Camera B	RMS EE[a,c]	RMS Work Station *or* ODS Camera[c]
PLB Camera B	PLB Camera A	PLB Camera C	RMS EE[a,c]	RMS Work Station *or* ODS Camera[c]
PLB Camera C	PLB Camera B	PLB Camera D	RMS EE[a,c]	Aft Pilot Station *or* ODS Camera[c]
PLB Camera D	PLB Camera C	PLB Camera A	RMS EE[a,c]	Aft Pilot Station *or* ODS Camera[c]
ODS Camera[c]	-	-	PLB Camera A	Aft Pilot Station
Mid Deck	-	-	Port Work Station	External Airlock[b]
External Airlock[b]	-	-	Mid Deck	ODS Camera[c]

[a] only when RMS is installed
[b] only when External Airlock is installed
[c] only when ODS is installed

Table 2: VC navigation

3.6 Atmospheric Wind

In addition to planetary surface elevation, the 2016 version of Orbiter Space Flight Simulator also implements atmospheric winds.
Unlike the real world, there is no weather forecast in Orbiter, so during landing it is easy to fly the vehicle into a wind situation that exceeds its (narrow) operating capabilities. For this reason, if atmospheric wind effects are enabled, intense monitoring of the vehicle performance during landing is required to ensure the vehicle reaches the runway.

4 SSV SYSTEMS

Contents

This section discusses in greater detail some of the Space Shuttle systems that are currently simulated.
For better organization, the information about Payloads is provided in section 5. In addition, information about the Upper Stages is located in section 6.

These are not meant to provide all information about the real Space Shuttle systems, but instead to provide a working knowledge required to understand what is happening in the simulation.

4.1 Data Processing System (DPS)

Contents

The DPS consists mainly of the General Purpose Computers (GPCs) and the software that runs in them, and several Multiplexer/Demultiplexers (MDMs), along with a few other systems. The 11 MDUs (Multifunction Display Units) are also part of the DPS.

4.1.1 GPCs

The real shuttle has 5 identical computers. Up to 4 of the 5 GPCs run the Primary Avionics Software System (PASS). The remaining computer runs the Backup Flight System (BFS). The PASS software is further divided into 3 Major Functions: *GNC* (Guidance, Navigation & Control), *SM* (Systems Management) and *PL* (Payload) software. The *GNC* software is responsible for controlling the orbiter during flight. During critical phases of flight, such as launch and entry, multiple GPCs will run the PASS *GNC* software simultaneously; this provides redundancy if one of the GPCs fails. The *SM* software monitors various orbiter systems. The *PL* software is not used during flight. The BFS was written separately from the PASS, and implements a subset of the PASS *GNC* functions. The BFS is meant to be used in the event of a PASS failure.

The *GNC* major function is divided into multiple OPS. Each OPS represents a different phase of flight. OPS 1 is used for launch, OPS 2 is used on-orbit, and OPS 3 is used for deorbit and entry. The GPC only has enough memory to store one OPS at a time, so the PASS software is divided into multiple memory configurations. Each memory configuration contains one OPS (except for MC 1, which is used during launch, and contains both OPS 1 (launch) and OPS 6 (RTLS)). To change from one OPS to another, the appropriate memory configuration has to be loaded onto the GPCs. Each OPS is further divided into Major Modes, which relate to specific phases of the mission. For example, OPS 2 (on-orbit) has 2 Major Modes: MM 201 (orbit coast) and MM 202 (Mnvr Exec). MM 202 is used for performing OMS burn, while MM 201 is used otherwise.
At the moment, SSV only simulates the PASS *GNC* software. Also, loading different memory configurations into the GPCs is not simulated. SSV assumes only one GPC is running, and does not simulate multiple GPCs performing the same operations as part of a redundant set. No major mode in OPS 6 is currently supported.

4.1.2 Multiplexer/Demultiplexer (MDMs)

The GPCs get much of their data from Multiplexer/Demultiplexer (MDMs), which gather and digitize sensor readings and switch positions. Commands from the GPCs to several electrical motors, valves or lights are also routed thru the MDMs.
Several of the MDMs are implemented in SSV, with many signals flowing thru them.

4.1.3 Multifunction Display Units (MDUs)

The shuttle originally had 4 CRT displays, and multiple analog instruments. The CRTs allowed the crew to interact with the shuttle computers, while the analog instruments displayed subsystem status and flight instruments. Starting with STS-101, the analog instruments were replaced with the MDUs. The shuttle has 11 MDUs: CDR 1 and 2 on panel F6; CRT 1, 2, and 3, and MFD 1 and 2 on panel F7; PLT 1 and 2 on panel F8; CRT 4 on panel R11; and AFD 1 in the aft station. In real life, the MDUs display either DPS displays, flight instrument displays, or subsystem status displays. The flight instruments and subsystem status displays replace the analog instruments, while the DPS displays are almost identical to the CRT displays.

In SSV, each MDU is an Orbiter Simulator MFD. CRT MFD, which is part of SSV, simulates the DPS displays. Section 4.2 describes the DPS displays that have been implemented so far. The 3 subsystem status displays (*OMS/MPS*, *APU/HYD* and *SPI*) have been implemented in CRT MFD. The flight instrument displays are only partially implemented. All displays in the Ascent/Entry Primary Flight Display are working except for full functionality of the ADI and HSI.

4.2 DPS Displays

The NASA DPS Dictionary describes each display in detail. This section lists the displays that have been implemented so far and describes the differences between the real shuttle and the SSV implementation.

4.2.1 ASCENT TRAJ

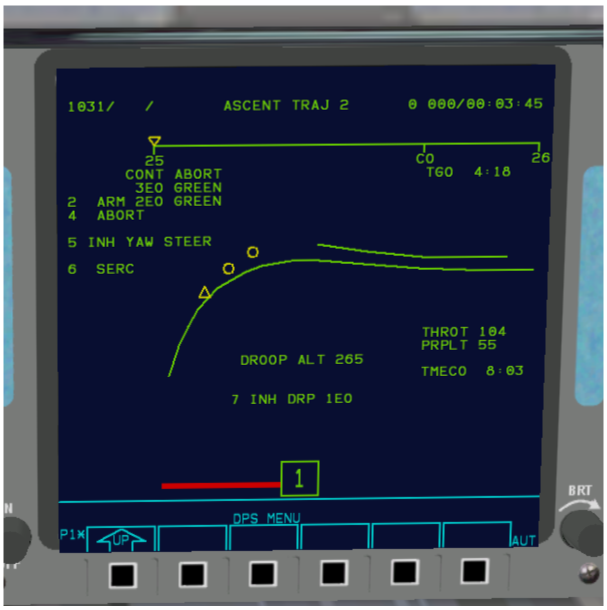


Figure 10: ASCENT TRAJ display

This display is used in MM 102 and MM 103 to monitor the vehicle's trajectory during ascent. The DROOP ALT digital output is not being driven. The ITEMs on this display are related to abort options and are not supported by SSV.

4.2.2 UNIV PTG

This display is used in MM 201, and is used to control the attitude of the orbiter. Most of the functions in this display have been implemented. ITEM 8 (TGT ID) only supports an entry of 2 at the moment, and ITEMS 9-13 are not supported. ITEM 20 (TRK) is not supported. Finally, ITEMs 22-24 (which affect how the attitude error is displayed) are not implemented.

4.2.3 OMS MNVR EXEC

This display is used in MM 104 (OMS 1 MNVR EXEC), MM 105 (OMS 2 MNVR EXEC), MM 106 (OMS 2 MNVR COAST), MM 202 (ORBIT MNVR EXEC), MM 301 (DEORB MNVR COAST), MM 302 (DEORB MNVR EXEC) and MM303 (DEORB MNVR COAST). It is used mainly to perform OMS engine burns to change the shuttle's orbit. This display is almost completely implemented in SSV. ITEMs 35-40 (FWD RCS dump and SURF DRIVE) have not been implemented yet.

4.2.4 OVERRIDE

Figure 11: OVERRIDE display

The OVERRIDE display currently only has implemented the 3 ITEM entries associated with the SSME maximum throttle, ITEM 42 to override the Entry Roll Mode switch and ITEM 45 to control the AerojetDAP Wraparound mode.

4.2.5 DAP CONFIG

This display is used in MM 201 and MM 202, and control the Digital Autopilot (DAP) settings. In real life, there are 15 DAP A configurations and 15 DAP B configurations; at any time, 1 DAP A and 1 DAP B configuration is active, and the crew selects between DAP A and B using the PBIs on Panels C3 and A6. Currently in SSV there is only 1 DAP A configuration and 1 DAP B configuration. As a result, ITEMS 1 and 2 (which select the active DAP A & B configuration) are not implemented. Also ITEMs 3 and 4 (which, in real life, select a DAP configuration and load it into the EDIT column) simply select between loading DAP A and DAP B into the EDIT

column.
Currently, the default DAP configurations are for the typical ISS flight as follows: DAP A is DAP A1 for Nominal usage, and DAP B is DAP B10 for Docking operations.

4.2.6 ORBIT TGT

This display is used in MM 201 and MM 202 to compute rendezvous burns. In real life, the state vectors for the rendezvous target are uploaded from Mission Control. In SSV, the name of the target vessel is specified in the scenario file. The real-life ORBIT TGT display can load rendezvous targets by specifying a TGT NO (ITEM 1); in SSV, each parameter has to be set individually. SSV doesn't support the EL parameter (ITEM 6), which allows the burn TIG to be computed to match a desired elevation angle; instead, the TIG must be specified. SSV can only be used to compute the T1 burn (ITEM 28), and not the T2 burn. In real life, the T2 burn computations are not used.

4.2.7 ENTRY TRAJ 1-5

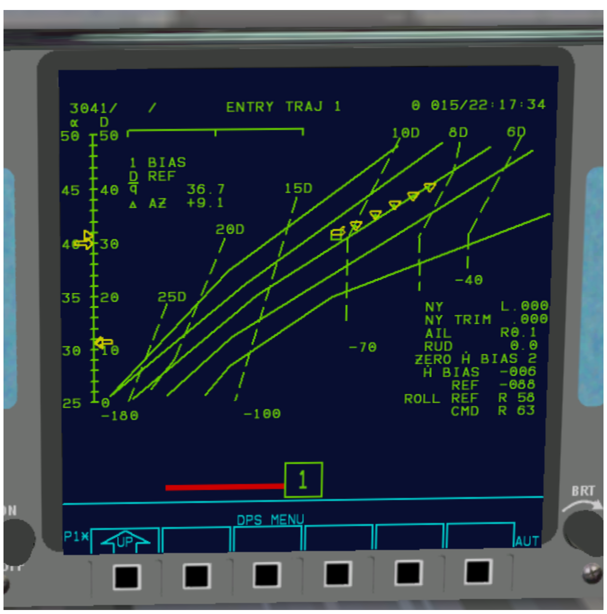


Figure 12: ENTRY TRAJ display

These displays are used during entry to monitor the vehicle's trajectory and AerojetDAP parameters. Currently only the phugoid scale and data is not driven and only ITEM 2 is supported.

4.2.8 VERT SIT 1-2

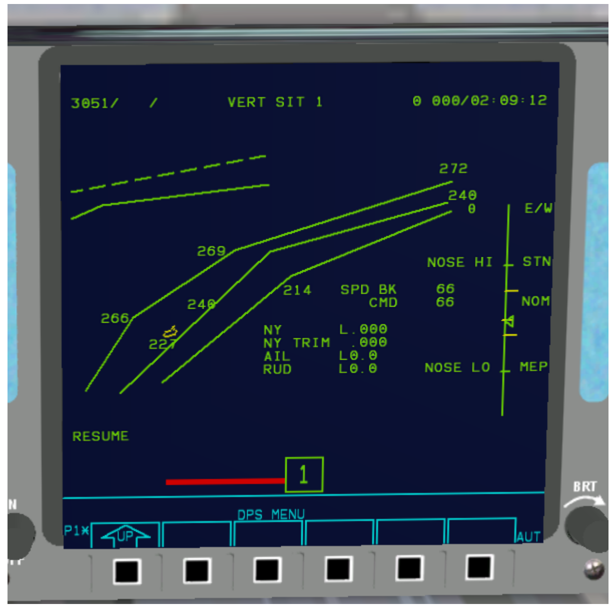


Figure 13: VERT SIT display

These displays are used during TAEM to monitor the vehicle's trajectory and AerojetDAP parameters. Currently only the Theta scale is not driven.

4.2.9 HORIZ SIT

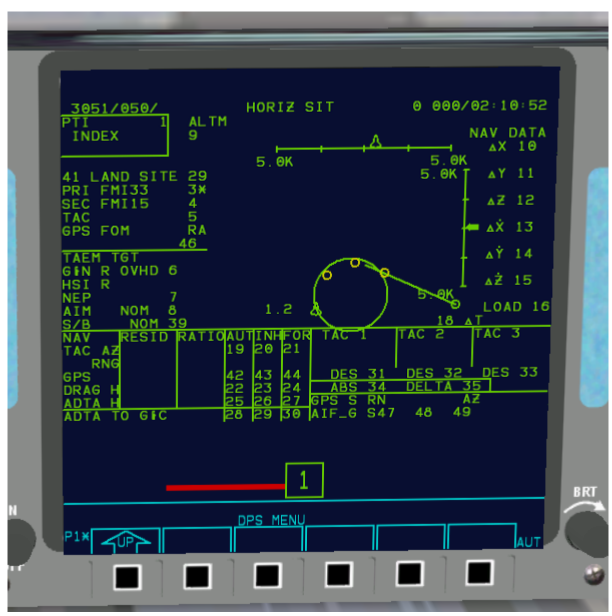


Figure 14: HORIZ SIT display

This display is used during deorbit and entry to specify the landing site and monitor the position of the shuttle relative to the HAC and the runway. The HORIZ SIT display in SSV is simplified compared to the real life version. Currently only ITEMs 3, 4, 6, 7, 8, 39 and 41 are supported. ITEM 41 selects the landing site, ITEMs 3 and 4 select either the primary or secondary runway. ITEM 6 downmodes from an overhead approach to a straight-in approach, ITEM 7 toggles between the Nominal Entry Point (NEP) or the Minimum Entry Point (MEP), ITEM 8 switches the aim point between nominal and close, and ITEM 39 switches between nominal, short and ELS (Emergency Landing Site) speedbrake configurations for final approach. These parameters all affect the entry autopilot, so they should be set before Entry Interface (EI).

The 45 landing sites for a mission are defined in the mission file (see 7). The full list of landing sites are listed in "<Orbiter installation>\Config\SSV_RunwayDB.csv", although not all are implemented yet. Table 3 shows the default list of landing sites currently supported by SSV.

SITE	Location	PRI RWY	SEC RWY
1	KSC	KSC 15	KSC 33
2	Ben Gerir	BEN 36	BEN 18
3	Moron	MRN 20	MRN 02
4	Zaragoza	ZZA 30L	ZZA 12R
5	Myrtle Beach	MYR 36	MYR 18
12	Ben Gerir	BEN 36	BEN 18
13	Moron	MRN 20	MRN 02
14	Zaragoza	ZZA 30L	ZZA 12R
16	Otis	FMH 32	FMH 23
20	St Johns	YYT 29	YYT 11
21	Gander	YQX 21	YQX 31
22	Banjul	BYD 32	BYD 14
23	Lajes	LAJ 15	LAJ 33
24	Vandenberg	VBG 30	VBG 12
26	Shannon	INN 06	INN 24
28	Koln/Bonn	KBO 14L	KBO 32R
29	Istres	FMI 33	FMI 15
32	Diego Garcia	JDG 31	JDG 13
33	Amberley/Tindall	AMB 15	PTN 14
34	Yokota	JTY 36	JTY 18
36	Bermuda	BDA 30	BDA 12
38	Mataveri	EIP 28	EIP 10
39	Hao	HAO 12	HAO 30
42	White Sands	NOR 17	NOR 23
43	White Sands	NOR 05	NOR 35
44	Edwards	EDW 15	EDW 18L
45	Edwards	EDW 22	EDW 04

Table 3: Default Landing Site Table

4.3 MEDS Displays

4.3.1 A/E PFD

Figure 15: A/E PFD

The Ascent/Entry Primary Flight Director display shows several parameters relevant to Ascent and Entry. Currently during launch and on-orbit, the attitude error needles are not properly driven, so they are not to be trusted (they are fully functional during entry). The ADI is operating in LVLH mode only (with yaw always zeroed when using Orbiter's original graphics engine), so the *ADI ATT* switches have no effect. During launch the HSI is not referenced from the target plane and the X-Trk value is not being driven.

4.3.2 ORBIT PFD

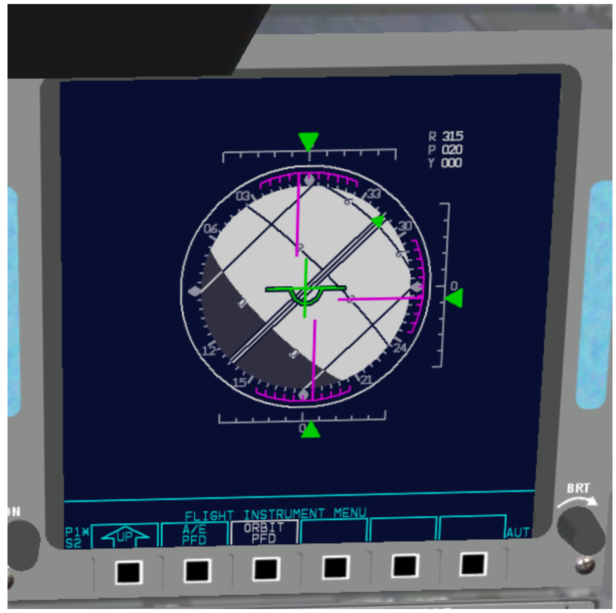


Figure 16: Orbit PFD

The Orbit Primary Flight Director is used for on-orbit display of vehicle attitude. Currently the attitude error needles currently are not being driven properly, so they are not to be trusted. The ADI currently operates only in the LVLH mode only (with yaw always zeroed when using Orbiter's original graphics engine), so the *ADI ATT* switches have no effect.

4.3.3 OMS/MPS

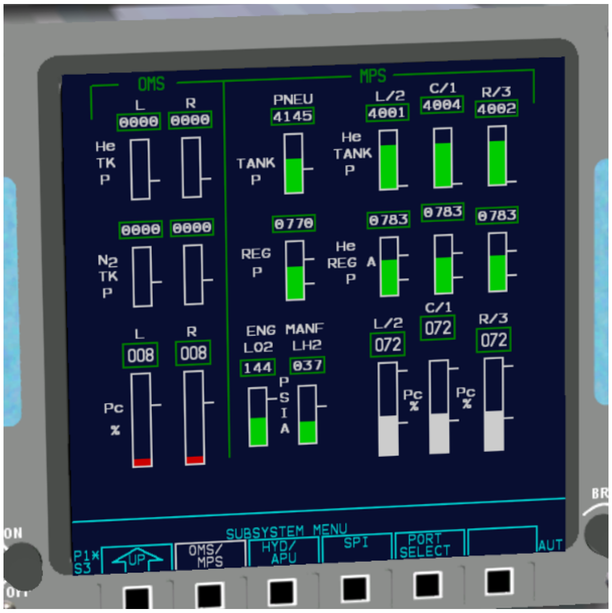


Figure 17: OMS/MPS display

The OMS/MPS display provides information about various pressures in the OMS and MPS systems. The OMS He TK P and N2 TK P meters are not driven.

4.3.4 APU/HYD

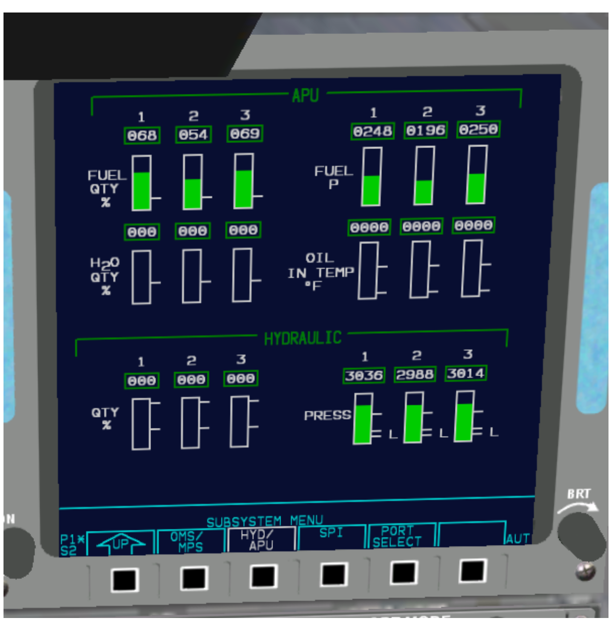


Figure 18: APU/HYD display

The APU/HYD display shows pressures, quantities and temperatures related to the hydraulic system. The APU H2O QTY %, OIL IN TEMP °F and HYDRAULIC QTY % meters are not driven.

4.3.5 SPI

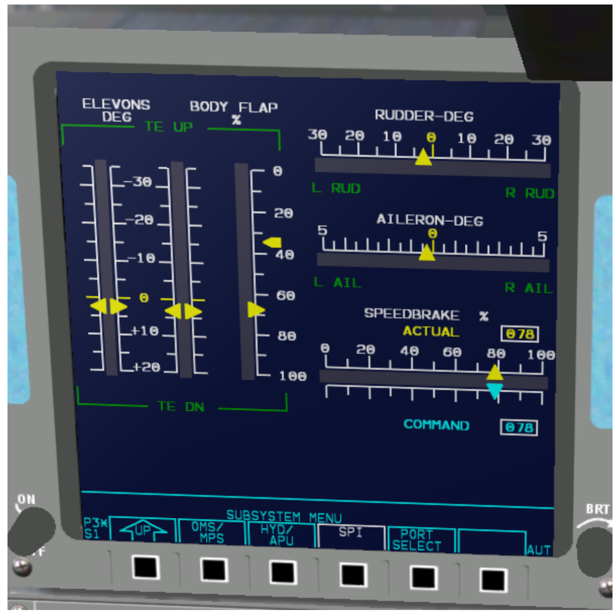


Figure 19: SPI display

The SPI display shows the position of the Orbiter Vehicle's aerosurfaces.

4.3.6 Maintenance

The MEDS maintenance displays are currently not being driven.

4.4 Caution & Warning (C&W)

To verify correct vehicle operation, several hundreds of parameters are monitored by the Caution & Warning system (C&W), and visual and aural alerts are given to the crew when something is wrong. The C&W is composed of 2 parts: the Primary C&W, which is a hardware system, and the software-based Backup C&W.
The Primary C&W system compares sensor voltages to pre-defined limits to verify subsystem temperatures, pressures and other parameters. The Backup C&W also checks several subsystem parameters, in addition to alerting the crew when an off-nominal situation occurs (e.g., detection of a SSME failure).
The Primary C&W system alerts the crew via the C&W light matrix on Panel F7 and Master Alarm lights, and also the Master Alarm sound. The Backup C&W system alerts the crew with fault messages in the CRT displays, and relies on the Primary C&W iluminate lights on Panel F7 and to generate the Master Alarm sound and Systems Management tone. The parameters of the Primary C&W system can have their limits changed or have their checks inhibited via controls on Panel R13U.
Currently the Primary C&W system only verifies the MPS He and Manifold pressures and the Hydraulic system pressures, and only a few GNC-generated Backup C&W alerts exist.

4.5 Orbiter Boom Sensor System (OBSS)

After the Columbia accident, the Space Shuttle introduced the Orbiter Boom Sensor System (OBSS), to effectively extend the reach of the RMS, thus allowing the inspection of the TPS in areas that could not be checked with the RMS alone. The OBSS has a sensor package on the tip to record TPS condition and 2 Grapple Fixtures (GF) for the RMS to maneuver it.
In the current implementation, the OBSS is completely passive.

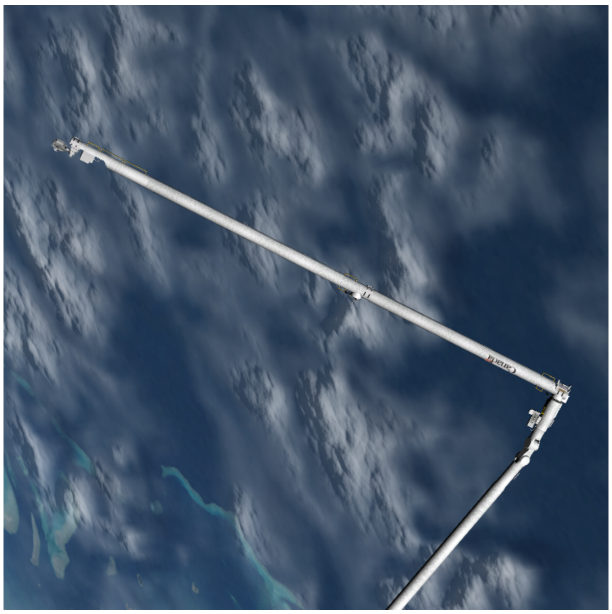


Figure 20: Orbiter Boom Sensor System

4.6 Launch Pads

SSV can be launched from 2 launch pads: Launch Complex 39 (LC39) at the Kennedy Space Center in Florida, from where all Space Shuttle missions were launched, or from Space Launch Complex 6 (SLC-6) at the Vandenberg Air Force Base in California, where polar-orbit missions were planned to be launched starting in 1986.

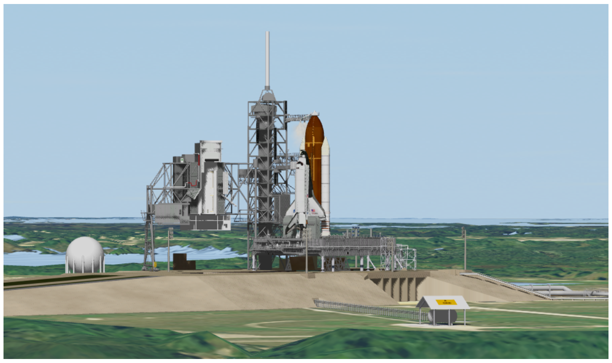


Figure 21: Launch Complex 39

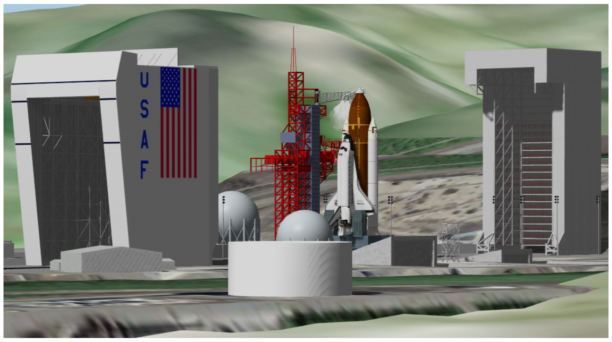


Figure 22: Space Launch Complex 6

Most pad structures are controlled automatically during the countdown, but manual control is available for all of them via a dialog window which is opened by the keys Ctrl+Space.
LC39 is available in 8 types:
⇒ 1981, the original STS-1 pad (not implemented yet, currently similar to the 1982 version);
⇒ 1982, new GVA GOX vent pipes;
⇒ 1983, RBUS (Rolling Beam Umbilical System) porch added;
⇒ 1985, RBUS added;
⇒ 1986, 'hypothetical' pad version with RBUS and OWP (Orbiter Weather Protection);
⇒ 1988, OWP added and RBUS removed;
⇒ 1995, hammerhead crane truss removed;
⇒ 2007, last pad iteration without the hammerhead crane and with a new lightning mast.

4.7 Launch Control Center

The Launch Control Center (LCC) vessel controls the countdown clock, issues commands to the launch pad and Space Shuttle vehicle and monitors their status during the countdown. User interaction with the LCC vessel is done via the LCCMFD.

The LCCMFD (Ctrl+T) allows the user to control the final 9 minutes of the countdown. Using the MFD buttons, the user can resume the countdown clock after a hold is called automatically due to violation of a Launch Commit Criteria parameter, and can also insert holds manually. In addition to the status of the final 5 hold points, the T0 time and countdown clock are also displayed. The countdown clock is also shown in the debug line (lower left corner of the window).

The launch pad Firex systems are also controlled from the LCCMFD. Using the (Left/Right)Shift+1 keyboard keys, operation of the Orbiter SSME Water Deluge System (SSME Heatshield) is controlled. This system is activated automatically after a pad abort, and is manually shutdown. (Left/Right)Shift+2 and (Left/Right)Shift+3 control the operation of the LH2/LO2 T-0 Water Deluge System (T0 Umbilicals) and the Orbiter Skin Spray System (Orbiter Skin), respectively. The current status of the 3 systems is displayed in the LCCMFD.

4.8 Crawler Transporter

The Crawler Transporter vessel allows the transfer of the MLP (with or without the Space Shuttle launch vehicle) from the VAB to the Launch Pad, and back. Currently all major functionalities of the Crawler are supported.

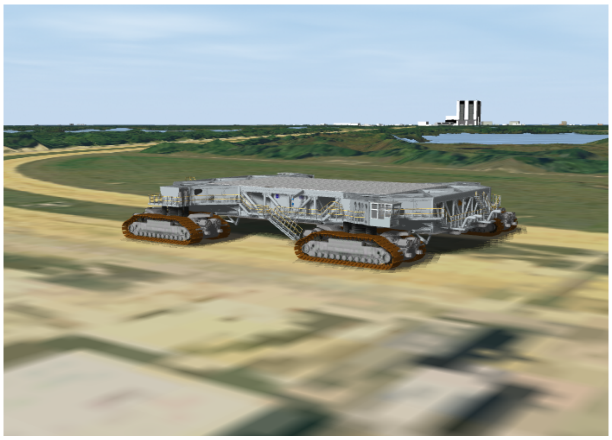


Figure 23: Crawler Transporter

The Crawler Transporter is available in 2 versions:
⇒ a 1980 version, used for most of the Space Shuttle Program;
⇒ the later version, with modifications related to sound attenuation, among others.

4.8.1 Cabin selection

The Crawler Transporter has 2 cabins from which it can be controlled: Cabin-3 at the front, and Cabin-1 at the rear. The selection, or deselection, of a cabin for control is made by depressing the "CAB ACK" PBI on the right panel, and the selection state is indicated by the "Cab Selected" light. When only one cabin is selected, it will be in control and the "Cab In Control" light will be illuminated in the cabin in control.

4.8.2 Motion

The Crawler Transporter motion is controlled by 3 mode PBIs and a speed control knob.
Forward motion is commanded by the FWD PBI, and aft motion is commanded by the REV PBI. The direction always referenced on the cabin in control. The NEUT PBI disengages the engine from the tracks.
The speed knob is controlled by the + and - NumPad keys, which will respectively increase and decrease the commanded speed. The actual Crawler speed is indicated in the top of the center panel.
The Crawler has a service brake, which is actuated by pressing the B key, and a parking brake controlled by the BRAKE PBI on the center panel.

4.8.3 Steering

The Crawler Transporter steering is controlled with a steering wheel, located in the center console. The steering wheel is controlled by the 1 and 3 NumPad keys, for left and right turns respectively. Additionally, the 5 NumPad key can be used for immediate steering wheel centering.
The Steer Mode PBI, on the right console, controls the steering wheel scale: the normal +/-6° setting provides the most direct control of the steering by allowing 6 degrees to be commanded, as labeled in the steering wheel; while the +/-2° option only allows a maximum of 2 degrees of steering to be commanded at full steering wheel deflection, thus allowing for more sensitive directional control.
The Crawler has different 3 modes of steering, selected by PBIs on the right console: Great Circle (G CIRC) mode allows the Crawler to go around corners by turning the forward drive trucks in the opposite direction to the aft drive trucks; Independent (INDEP) mode, allows independent control of each end of the Crawler by having each cabin controlling only the drive trucks on its end; Crab (CRAB) mode allows the Crawler to move diagonally, without changing the heading, to sort out any lateral misalignments with a target, by commanding all drive trucks in the same direction.
The desired steering angles of the drive trucks on each end of the Crawler are displayed on the right console, as is the actual steering input.

4.8.4 Jacking, Equalization and Leveling system

The Jacking, Equalization and Leveling system (JEL) is comprised of 16 hydraulic cylinders, 4 in each corner of the Crawler, that are responsible for maintaining the Crawler Transporter leveled, and also allowing it to lift the MLP off its stands. Each hydraulic cylinder can be extended a maximum of 6 feet.
The AVERAGE HEIGHT gauge on the right console is showing the averaged height between all four corners. When the Crawler is exactly level (not ascending or descending the pad ramp) the gauge shows the extension all JEL cylinders.
Crawler jack-up is commanded by the Ctrl+K keys, and jack-down by the Ctrl+J keys. The Crawler can be commanded to 3 height levels, in order of increasing height:

(1) travel height, the normal height for Crawler travel; (2) docking height, the height to pickup and harddown the MLP; (3) clearance height, the maximum height to raise the MLP above the mounts.

4.8.5 Laser Docking System

The Laser Docking System allows the driver to visualize the lateral alignment between the Crawler and its target (either the MLP or the mounts if the MLP is attached). It is the yellow rectangular box on top of the right console. None of the switches except for the CAB 1/3 switch, which allows the LDS display to switch between the receivers mounted on each end, so that the driver can correct any rotational misalignments without communicating with the driver in the opposing cab. It's a steer-to alignment system, so if the black alignment bar is on the right you need to steer to the right, and if it is on the left you need to steer to the left. The goal is to get the alignment bar in the very center of the display, for both Crawler ends.

4.8.6 Procedures and general notes

Do note that the Crawler accelerates very much like a train so don't expect on the dime stop, always plan your speeds ahead especially when you are approaching your target (your speed should then be below 0.1 MPH).
Make sure you always plan your trajectory, as the Crawler has a slow response to steering inputs.
Attaching/detaching the MLP to the Crawler can only be done in the docking height. The proper procedure is to fully jack down the Crawler once the MLP has fully cleared the mounts either in the VAB or at the pad.

4.8.7 Compatibility

The SSV Crawler is compatible with any launcher platform as long as the attachment point has the ID of XMLP. The attachment point on the launcher platform should be on the very bottom of the platform.

5 PAYLOADS

Contents

Like the real Space Shuttle, SSV allows the user to place payloads in the Payload Bay (PLB). This chapter explains how payloads (satellites, space station modules, small experiment canisters, etc) can be attached to the PLB. Details are also provided about the attachment needed for payloads to be grappled by the RMS. In addition to basic payload information, this section contains data on how payloads can be used in SSV.

5.1 Payload Types

SSV groups payloads into 5 categories, according to the location and way they are attached in the PLB: "Active", "Passive", "Bay Bridge", "Manipulator Position Mechanism (MPM)" and "Upper Stage".
The first 2 groups of payloads represent the most common payloads. They are attached to the PLB with payload retention latches capable of holding the largest payloads the Space Shuttle can carry. "Active" payloads can be released and latched (e.g., LDEF), while "Passive" payloads remain in the PLB for the duration of the mission (e.g., Spacelab).
The "Bay Bridge" payloads are mounted in place of the payload bay attachment bridges, on the PLB sill longerons or the keel. They are usually brackets for mounting small payloads (e.g. Get Away Special (GAS) Canisters).
The Manipulator Position Mechanism (MPM) payloads attach to the MPM pedestals. The most common example of this type of payload is the Orbiter Boom Sensor System (OBSS).
The Upper Stage payloads are detailed in section 6.

5.1.1 Active

These payloads are connected to the PLB with active latches, allowing the payloads to be released and latched as needed. Bridges spanning the payload bay frames at the sill longeron and keel provide mounting locations for the latches, in predetermined locations at every 3.933 inches. These locations are identified by their PLID number. A maximum of 5 "Active" payloads can be defined for a mission.
Each payload can specify up to 12 latches (4 port, 4 starboard and 4 keel), although payloads usually use a 3-point (2 longeron, 1 keel) or 5-point (4 longeron, 1 keel) system. One of these attachments is defined to be the "main" attachment, which corresponds to the vessel attachment point. The attachment should usually be placed at one of the keel latches, but it is permitted to be placed at one of the sill longeron latches. Each latch is wired to a latch control system to allow for its operation from controls on panel A6U.
Sill longeron latches can be fitted with extended guides, for ease of deploy and latch operations.
The location of the attachment point is the center of the latches. At the keel, that is Yo 0.0 and Zo+305.025 for bays 1-11, Zo+308.40 for bay 12. For attachments at the sill longeron, the location is Yo+/-93.925 and Zo+414.05. Each PLID is fixed at a longitudinal (Xo) position. The forward-most PLID is 154 at Xo+608.80, and the aft-most PLID is 330 at Xo+1303.00. A section of the 90-inch radius payload envelope, with the location of the available attachment locations is show in figure 24.
The attachment direction and rotation vectors for a keel-attached payload are shown in figure 25, and for longeron-attached payloads in figure 26.

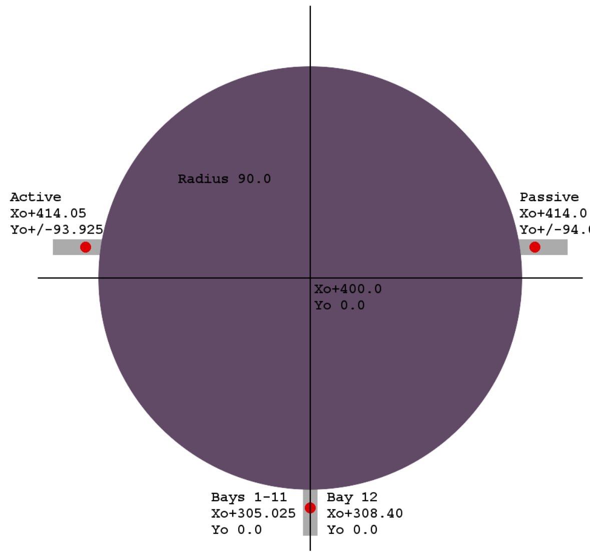


Figure 24: Section of payload envelope with attachment locations

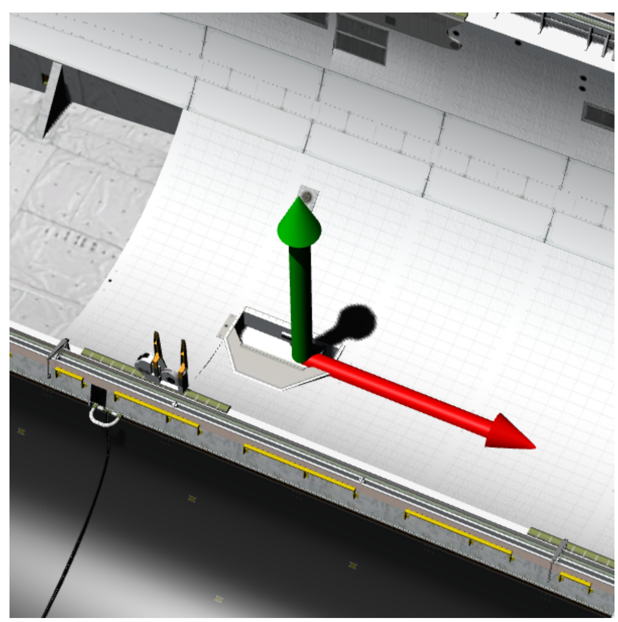


Figure 25: Active and Passive payload keel attachment direction (green) and rotation (red)

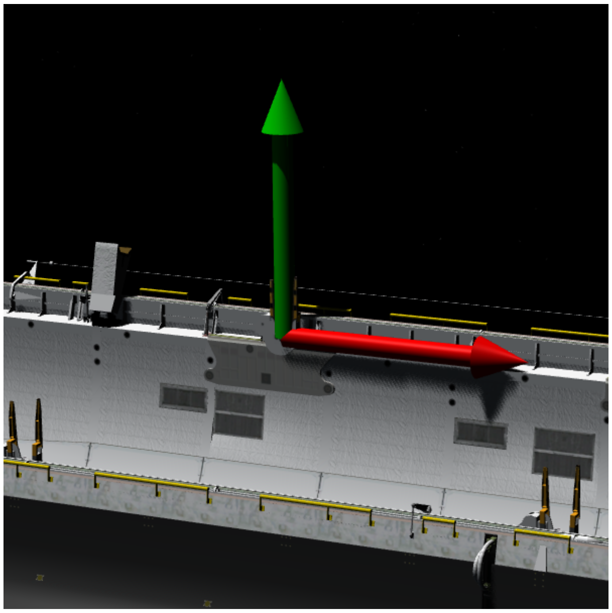


Figure 26: Active and Passive payload longeron attachment direction (green) and rotation (red)

5.1.2 Passive

If a payload doesn't need to be released in-flight, it is attached to the PLB with passive latches. Up to 5 "Passive" payloads can be defined.
The attachment scheme is similar to the one used for the "Active" payloads, also with a similar 12 latch limit. The location of attachments defined at the keel is Yo 0.0 and Zo+305.025 for bays 1-11, Zo+308.40 for bay 12. If defined at the sill longeron, the location is Yo+/-94.0 and Zo+414.0. A section of the 90-inch radius payload envelope, with the location of the available attachment locations is show in figure 24.
The attachment direction and rotation vectors for a keel-attached payload are shown in figure 25, and for longeron-attached payloads in figure 26.

5.1.3 Bay Bridge

"Bay Bridge" payloads are mounted on the sill longeron and ring frame attachments, usually used for the payload bay attachment bridges, effectively replacing them. These payload attachments are not releasable in during the mission, and are usually used to attach mounting plates for other payloads (e.g. payload canisters). A combined total of 8 "Bay Bridge" payloads (port, starboard and keel) can be defined. All 13 bays are available for the sill longeron bridges, but only 12 bays (1 thru 12) for the keel bridge.
The attachment point is defined at the center point between the 2 PLB ring frames bordering the bay at Zo+408.0 and Yo+/-94.0 for the sill longeron bridges, and Zo+306.0 and Yo 0.0 for the keel bridges. The Xo coordinates for the bay limits and the location of the attachment are listed in Table 4

Bay	Forward ring frame	Attachment location	Aft ring frame
1	582.0	609.0	636.0
2	636.0	664.5	693.0
3	693.0	721.5	750.0
4	750.0	778.5	807.0
5	807.0	835.0	863.0
6	863.0	891.0	919.0
7	919.0	949.25	979.5
8	979.5	1009.75	1040.0
9	1040.0	1065.165	1090.33
10	1090.33	1115.5	1140.67
11	1140.67	1165.835	1191.0
12	1191.0	1220.0	1249.0
13	1249.0	1278.0	1307.0

Table 4: Bay Xo Coordinates

The attachment direction and rotation vectors for a longeron-attached payload are shown in figure 27, and for keel-attached payloads in figure 28.

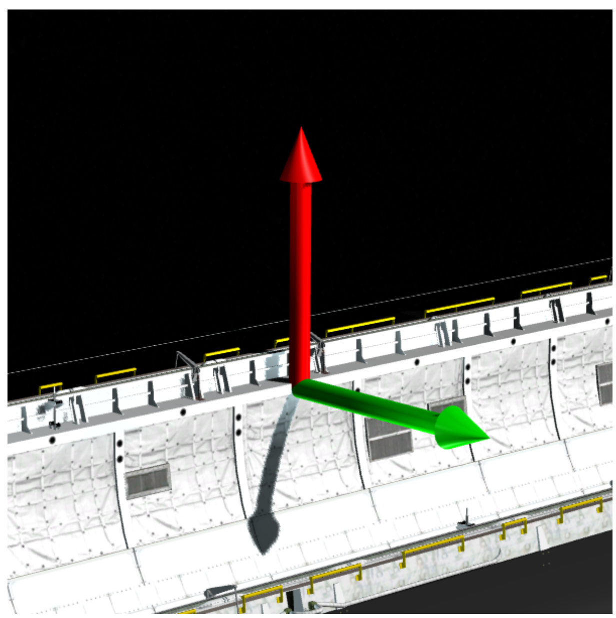


Figure 27: Bay bridge payload longeron attachment direction (green) and rotation (red)

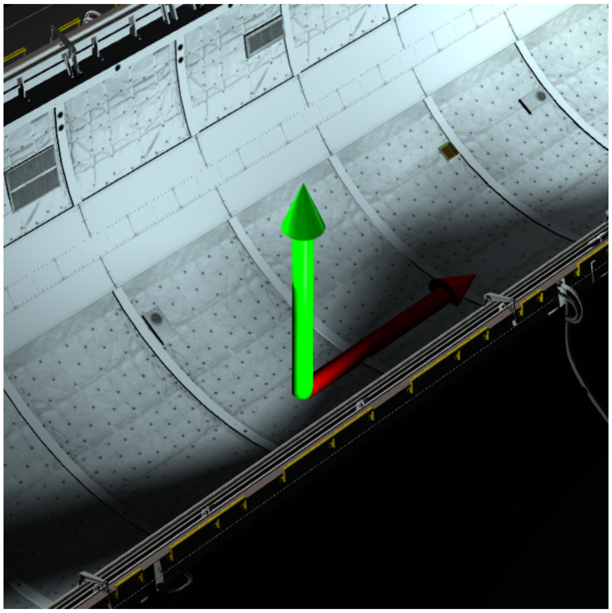


Figure 28: Bay bridge payload keel attachment direction (green) and rotation (red)

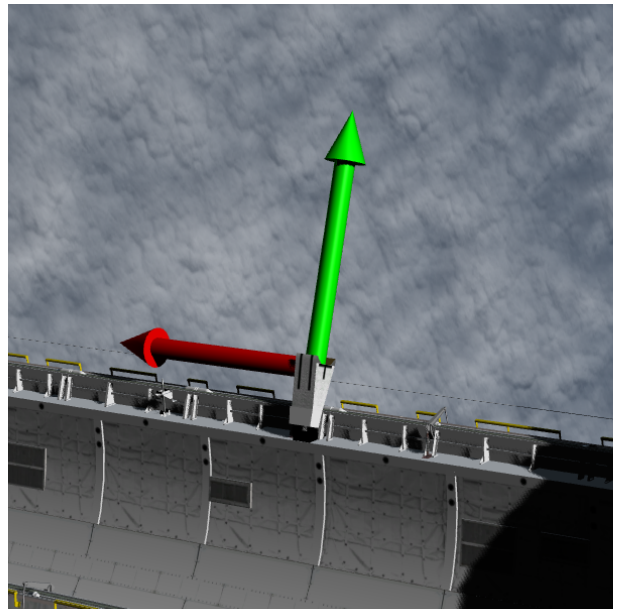


Figure 29: MPM payload attachment direction (green) and rotation (red)

5.1.4 MPM

In addition to providing a mounting place for the RMS, the Manipulator Positioning Mechanism (MPM) pedestals can also be used for payload purposes (when the RMS is not used). These payloads can be latched and released from the 4 MPM pedestals with switches on panel A8A2. The number of MPM pedestals needed for a payload, and the upper pedestal mesh, are configurable in the mission file (see 7). The OBSS is an example of a MPM payload. MPM upper pedestal meshes for the OBSS are provided in SSV.
The attachment point for these payloads is located inside one of the MPM pedestals, and the payloads must have its attachment in the strike-bar. The Xo location of the pedestals is listed in table 5.

Pedestal	Xo coordinate
Shoulder	679.5
Forward	911.05
Mid	1189.0
Aft	1256.5

Table 5: MPM pedestal Xo Coordinates

The attachment direction and rotation vectors for a payload are shown in figure 29.

5.2 RMS

For the RMS to grapple a payload, it much have an attachment with the ID "G". The attachment must be placed at the surface of the Grapple Fixture plate, centered in the cam/arm assembly.
The attachment direction and rotation vectors for the RMS End Effector are shown in figure 30.

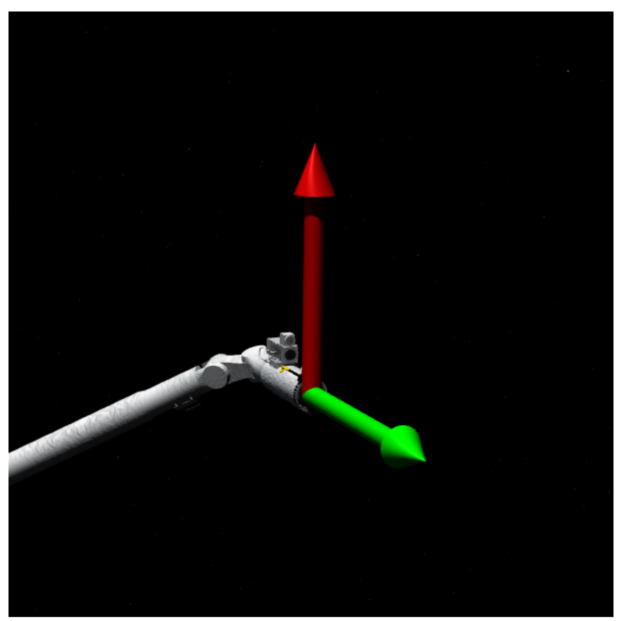


Figure 30: RMS payload attachment direction (green) and rotation (red)

6 UPPER STAGES

Contents

Currently SSV supports the 2 biggest and more powerful Space Shuttle upper stages: the Inertial Upper Stage and Centaur. These 2 upper stages allow the Space Shuttle Vessel add-on to launch payloads to anywhere from Geostationary Orbit (GEO) to the depths of the Solar System.

6.1 Inertial Upper Stage

Contents

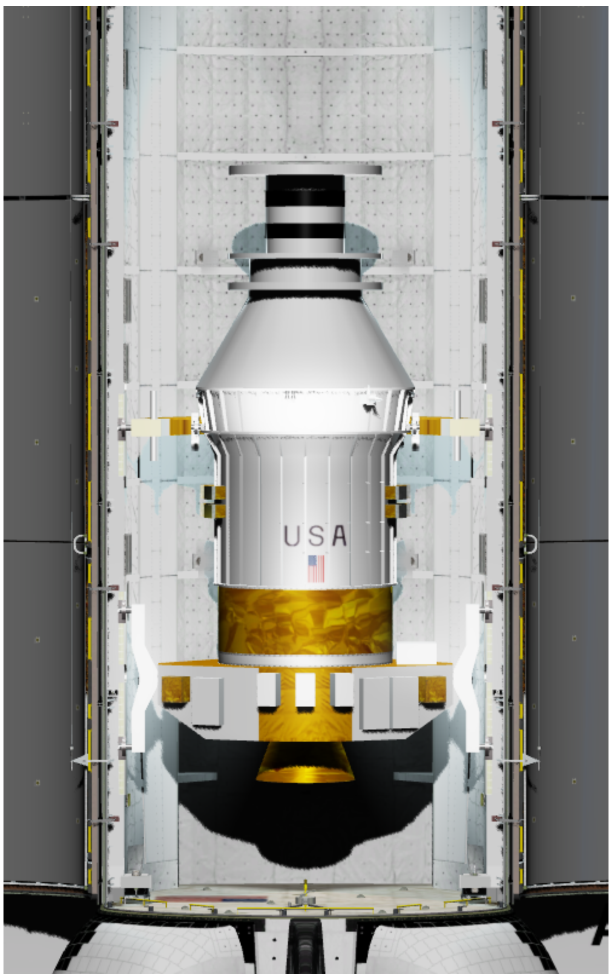


Figure 31: Inertial Upper Stage installed in the payload bay with SSV_DemoSat

6.1.1 Description

The Inertial Upper Stage, or IUS, is a 2-stage solid propellant vehicle (also known as IUS 2-Stage) used in several Space Shuttle missions to boost satellites into GEO and space probes into Earth escape trajectories. Thrust is provided by one Solid Rocket Motor (SRM) in each stage, and the Reaction Control System (RCS) allows 3-axis control of the stage, and also translation in the +Z direction (forward).

6.1.2 Configuration

The IUS can be installed in the payload bay in 2 possible positions: the forward position or the aft position (for large payloads). The position choice is defined in the mission file (section 7).

The standard IUS configuration features 2 RCS tanks each with 55Kg of propellant. An additional tank can be used, for a total of 3, or only one tank can be used to reduce mass. In addition to the standard 2 omni-directional antennas in the 2^{nd} stage, a further 2 can be added, for a total of 4. Due to the nature of the solid propellant motors, fine control of the ΔV is impossible during the burn, so the propellant quantity must be carefully set. Both SRMs have the capability to be offloaded up to 50%.

The number of RCS tanks, omni-directional antennas and SRM propellant offload quantity are controlled by mission file parameters (section 7).

6.1.3 Performance

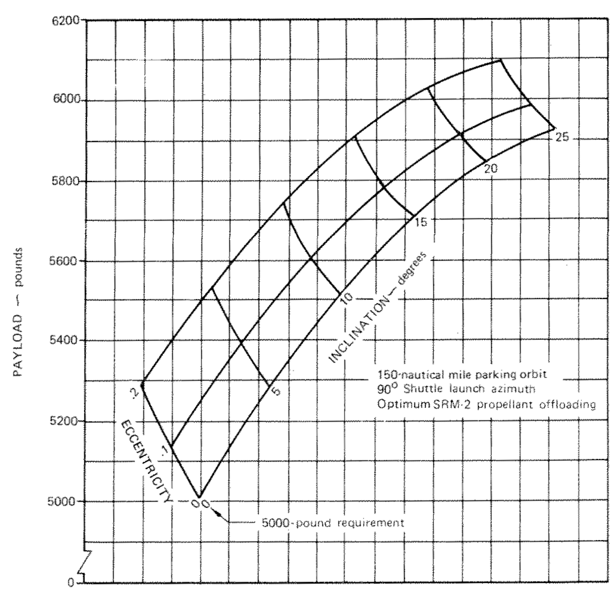


Figure 32: IUS payload capability to GEO

Specially suited for GEO missions, the IUS was designed to insert a 5000-pound (2268 Kg) payload into geostationary orbit. It can however launch heavier payloads at the expense of final orbit eccentricity and/or inclination. The relationship between payload mass and the corresponding achievable orbital parameters for a GEO mission is shown in figure 32.

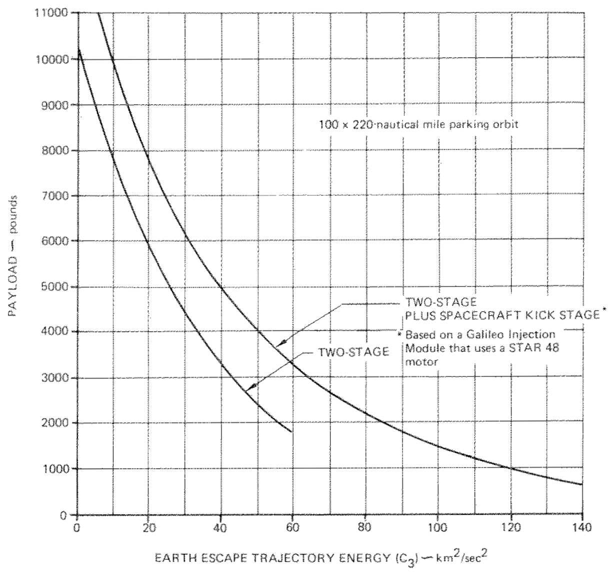


Figure 33: IUS payload capability for an Earth-escape trajectory

Although designed for Earth-orbit missions, the IUS can also inject spacecrafts into Earth-escape trajectories. More capability can be obtained by including an additional stage in the spacecraft. The payload capability of the IUS versus C3 energy is presented in figure 33.
Figure 34 shows the allowable payload envelope for both IUS positions. While the aft IUS position allows a payload with greater volume to be carried, it should only be used when necessary due to OV c.g. limits.

6.1.4 Airborne Support Equipment

The Airborne Support Equipment (ASE) is the interface between the IUS and the OV. Before IUS deployment, the ASE provides the IUS with electrical power and communications, and serves to secure it inside the payload bay. The ASE has a tilt table, to which the IUS is attached, allowing it to be raised above the payload bay for deployment. The ASE also has a boom-mounted IUS umbilical, that must be released before IUS deployment.

6.1.5 Deployment

The IUS deployment sequence is controlled by panel L10.
TODO
Inhibits are placed on the operation of the RCS and of the 1^{st} stage motor, as to protect the orbiter vehicle. At deployment, timers are started to remove those inhibits. The status of those timers is displayed in the SSV_IUS MFD (Ctrl+T), as well as the remaining RCS propellant.

6.1.6 Autonomous flight control

After separation from the ASE and the engine inhibits have been removed, the IUS is controlled by using the standard Orbiter keys. The "+" key is used to ignite the SRMs. During SRM burns the attitude in the pitch and yaw axis is controlled by gimballing the engine nozzle, while roll remains under RCS control.

WARNING

Engine gimballing is much more powerful than the RCS, so it must be used carefully so the stage is not put into a tumble that might be impossible for the RCS to stop after the burn.

Manual command for the engine gimbal is available and when there is no user input, the rates will be automatically nulled. Once ignited, the SRMs will burn to depletion.
After 1^{st} stage burnout, its separation is done by pressing the "Ctrl+G" key combination. After 1^{st} stage separation, the Extendable Exit Cone in the 2^{nd} stage will automatically deploy.
At the end of each SRM burn, the RCS can be used for velocity fine tuning.
After all the burns are performed, payload separation is done by pressing the "Ctrl+J" key combination.

6.1.7 Payload Interface

The connection between the IUS and its payload is done using a payload adapter. Its exclusive purpose is to interface the payload with the IUS and is considered a part of the payload, even though on payload deployment the adapter remains with the IUS.
The payload adapter is specified in the IUS vessel section of the mission file (section 7). For IUS payload developers, the payload adapter must be 2.89 meters in diameter at the IUS end, to correctly interface with the stage. The payload adapter can be a solid tapered cone as shown in figure 31 or a grid structure. SSV includes a demonstration payload adapter for interfacing the IUS with SSV_DemoSat.
The payload attachment is located in the longitudinal axis of the IUS. For the correct positioning of the attachment at the top of the payload adapter, its height

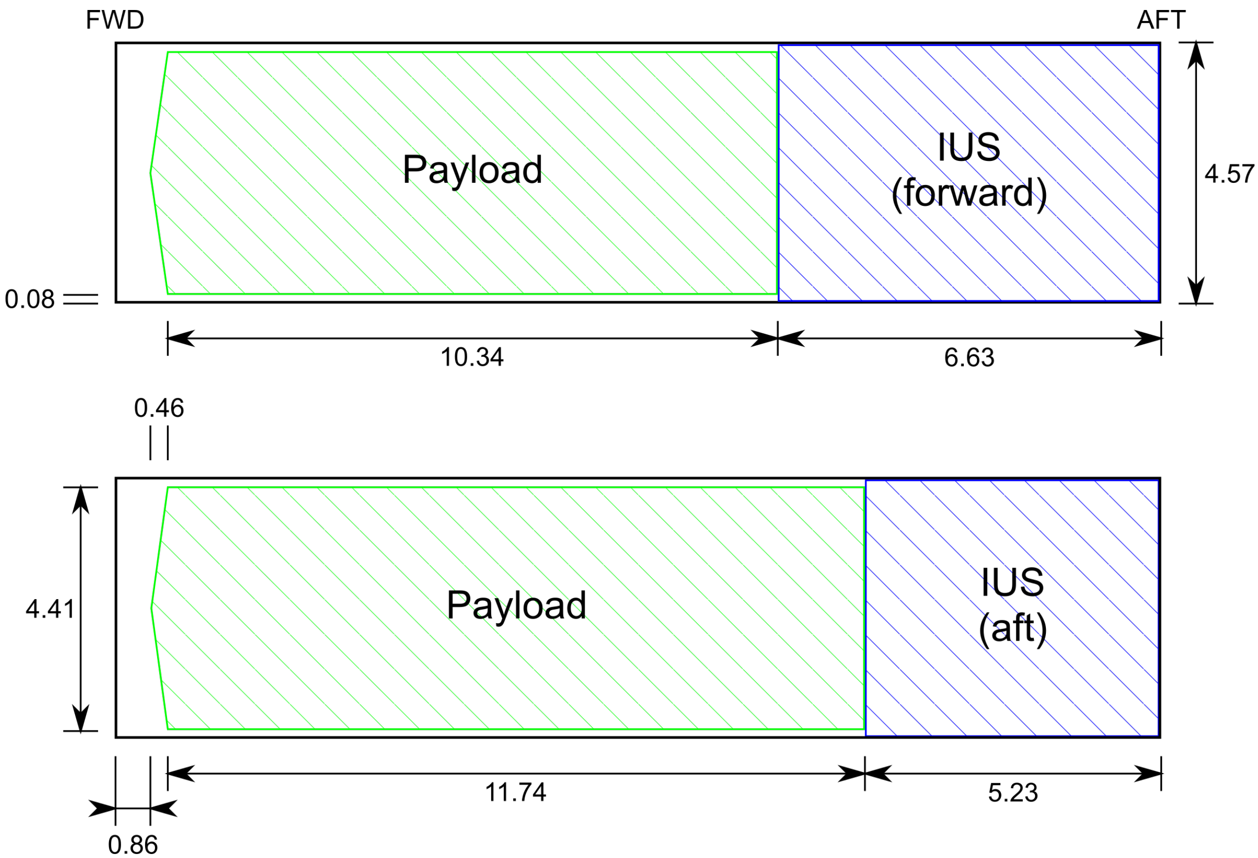


Figure 34: IUS payload envelope (dimensions in meters)

(the offset parameter) must be provided in the mission file. The attachment direction and rotation vectors are shown in figure 35.

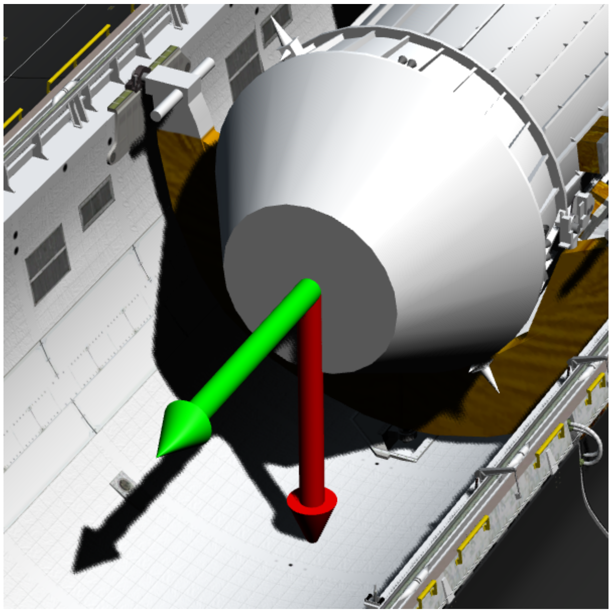


Figure 35: IUS payload attachment direction (green) and rotation (red)

6.1.8 Payload Commands

The IUS has the capability to send 8 discrete commands to its payload by pressing keys "Ctrl+1" thru "Ctrl+8". These commands can be used to deploy antennas or solar arrays before payload separation.
Each command sends a message to the payload's VESSEL3::clbkGeneric member function, with the message identifier 'VMSG_USER + 0x0101' and a message parameter corresponding to the command number (1 thru 8).

6.2 Centaur

Contents

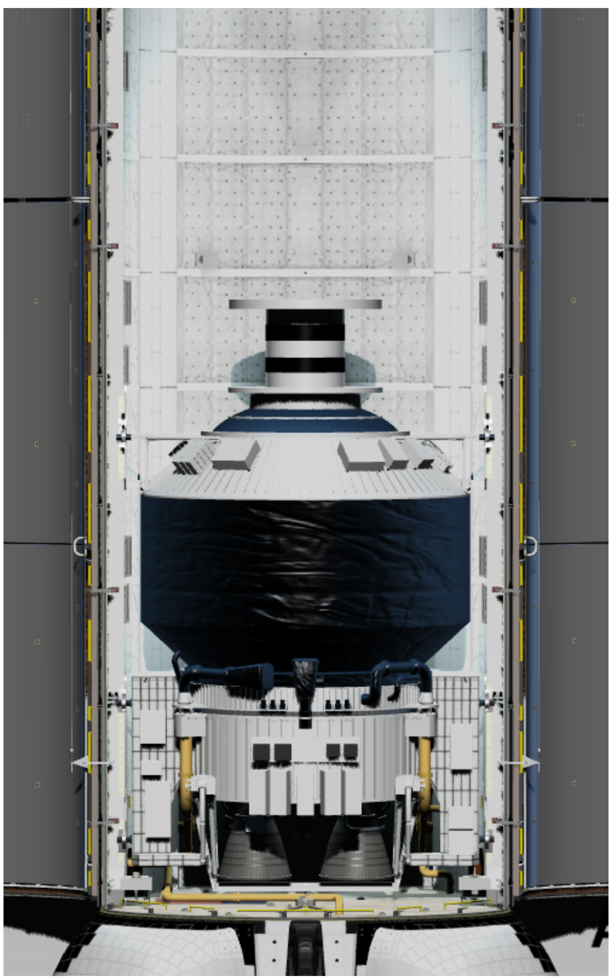


Figure 36: Centaur G installed in the payload bay with SSV_DemoSat

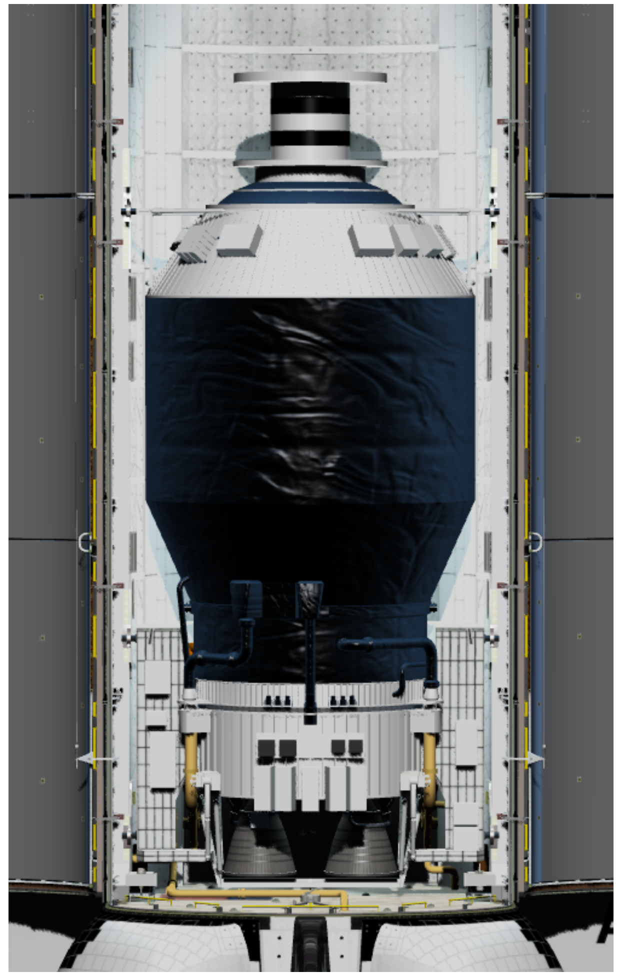


Figure 37: Centaur G Prime installed in the payload bay with SSV_DemoSat

6.2.1 Description

In the 1980s, NASA modified the Centaur upper stage with the intent to use it aboard the Space Shuttle to increase the payload capability of space probes and GEO satellites.

Two versions were developed: the Centaur G version was primarily for GEO satellite deployment missions, and the larger, more powerful Centaur G Prime for interplanetary payloads. In the aftermath of the Challenger accident, the Centaur was no longer considered safe enough to be used by the Space Shuttle, and so it was abandoned.
Thrust is provided by 2 RL-10 engines, and the Attitude Control System (ACS) allows 3-axis control of the stage, and also translation in the +Z direction (forward).

6.2.2 Performance

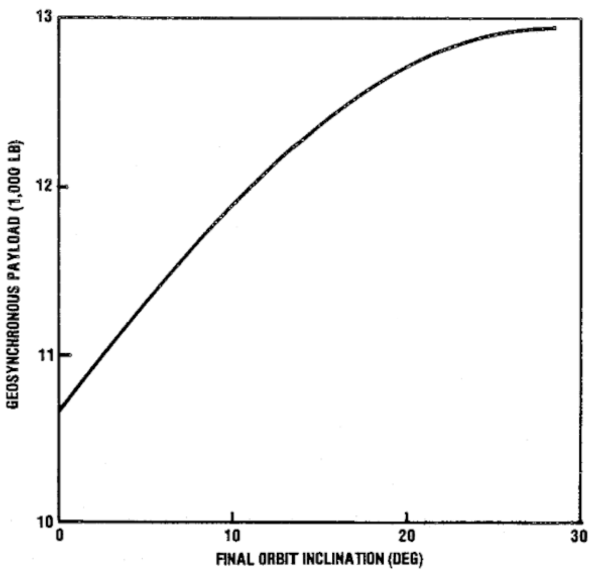


Figure 38: Centaur G payload capability for an GSO orbit

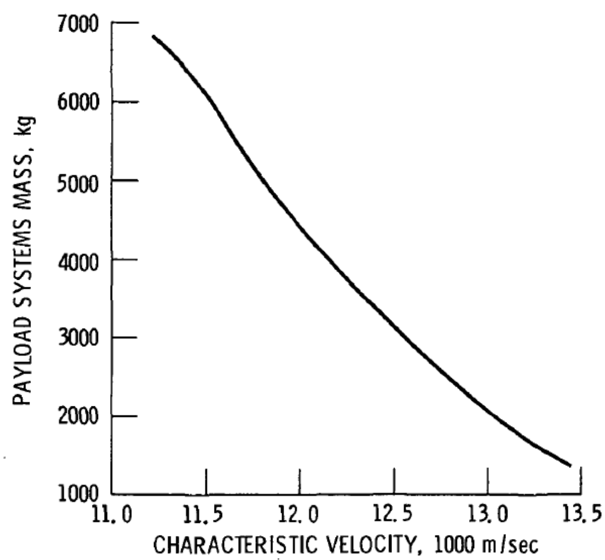


Figure 39: Centaur G payload capability for an Earth-escape trajectory

Although the Centaur G is suited for Geosynchronous Orbit (GSO) satellite missions, it is also capable of launching spacecraft into Earth-escape trajectories. Centaur G payload performance for GSO missions as a function of final inclination is show in figure 38, and payload performance for Earth-escape missions as a function of characteristic velocity in shown in figure 39.

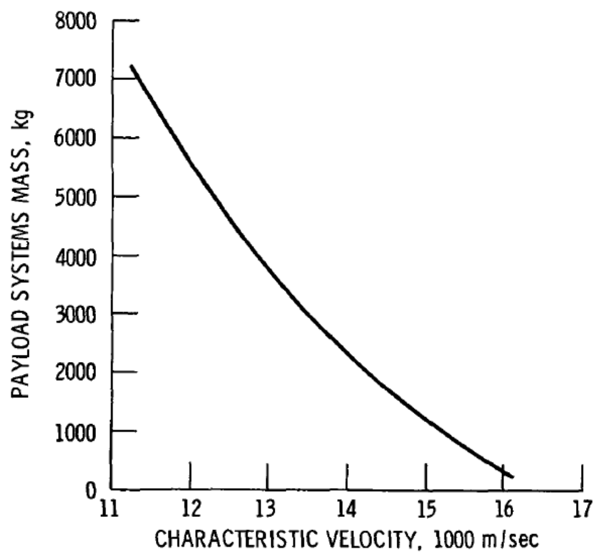


Figure 40: Centaur G Prime payload capability for an Earth-escape trajectory

The greater propellant capability of the Centaur G Prime gives it the performance needed to launch heavy spacecraft to other planets. A plot of payload mass versus characteristic velocity achievable with the Centaur G Prime in shown in figure 40.

Figure 41 shows the allowable payload envelope for both Centaur versions. The higher performance of the Centaur G Prime comes at a cost in allowable payload volume.

6.2.3 Centaur Integrated Support Structure

The Centaur Integrated Support Structure (CISS) is the interface between the Centaur stage and the orbiter vehicle. Before Centaur deployment, the CISS provides the Centaur with fluid connections for propellant loading and dumping, electrical power and communications, and serves to secure it inside the payload bay. The CISS has a tilt table, to which the Centaur is attached, allowing it to be raised above the payload bay for deployment.

6.2.4 Deployment

The deployment sequence is similar for both Centaur versions, and is controlled by panel L12U. A checklist is available in section 8.

Inhibits are placed on the operation of the ACS and of the RL-10 engines, as to protect the orbiter vehicle. At deployment, timers are started to remove those inhibits. The status of those timers is displayed in the SSV_Centaur MFD (Ctrl+T), as well as the remaining ACS propellant.

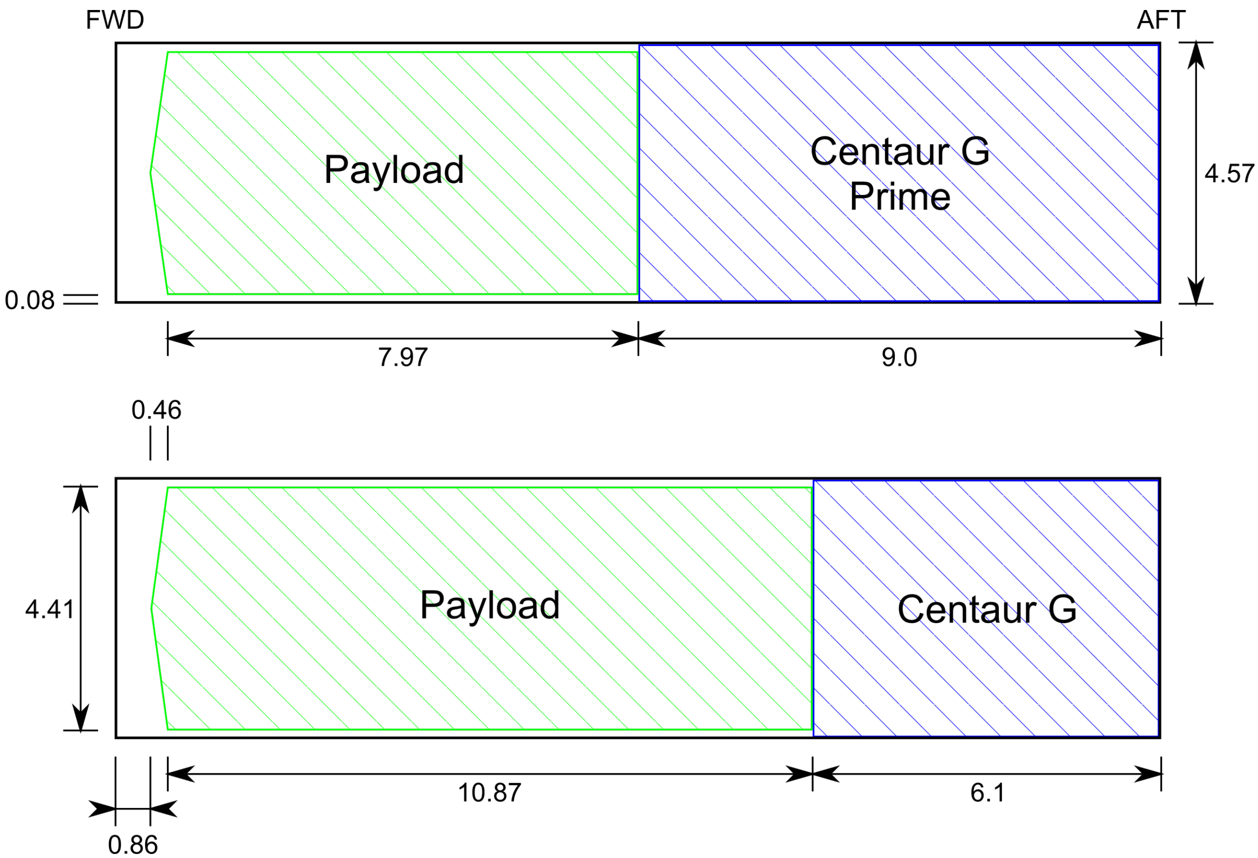


Figure 41: Centaur G and G Prime payload envelope (dimensions in meters)

6.2.5 Autonomous flight control

After separation from the CISS and the engine inhibits have been removed, the Centaur is controlled by using the standard Orbiter keys. The "+" key is used to initiate the start sequence for the RL-10 engines. The start sequence is a 270-second chill-down of the RL-10s concurrent with a propellant settling burn by the forward-thrusting ACS. After the chill-down is complete, RL-10 ignition occurs automatically. After the start sequence is initiated, the time remaining until ignition is shown in the SSV_Centaur MFD. Currently there are no restrictions on the number of times the RL-10 engines can be started. The "-" key is used to shutdown the engines once the desired ΔV has been achieved. During RL-10 burns the attitude in completely controlled by gimballing the engine nozzles.

WARNING

Engine gimballing is much more powerful than the ACS, so it must be used carefully so the stage is not put into a tumble that might be impossible for the ACS to stop after the burn.

Manual command for the engine gimbal is available and when there is no user input, the rates will be automatically nulled. After all the necessary burns are performed, payload separation is done by pressing the "Ctrl+J" key combination.

6.2.6 Payload Interface

The connection between the Centaur and its payload is done using a payload adapter. Its exclusive purpose is to interface the payload with the Centaur and is considered a part of the payload, even though on payload deployment the adapter remains with the Centaur.
The payload adapter is specified in the Centaur vessel section of the mission file (section 7). For Centaur payload developers, the payload adapter must be 2.74 meters in diameter at the Centaur end, to correctly interface with the stage. The payload adapter can be a solid tapered cone as shown in figures 36 and 37 or a grid structure. SSV includes a demonstration payload adapter for interfacing the Centaur with SSV_DemoSat. The payload attachment is located in the longitudinal axis of the Centaur. For the correct positioning of the

attachment at the top of the payload adapter, its height (the offset parameter) must be provided in the mission file. The attachment direction and rotation vectors are shown in figure 42.

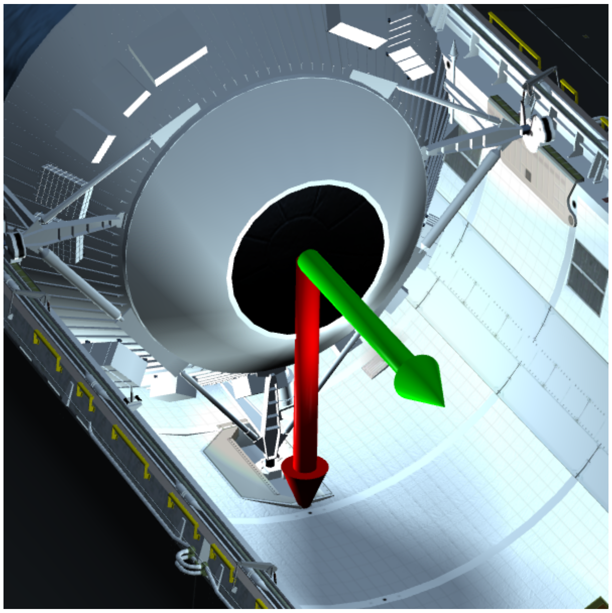


Figure 42: Centaur G and G Prime payload attachment direction (green) and rotation (red)

6.2.7 Payload Commands

The Centaur has the capability to send 8 discrete commands to its payload by pressing keys "Ctrl+1" thru "Ctrl+8". These commands can be used to deploy antennas or solar arrays before payload separation.
Each command sends a message to the payload's VESSEL3::clbkGeneric member function, with the message identifier 'VMSG_USER + 0x0101' and a message parameter corresponding to the command number (1 thru 8).

7 MISSION CONFIGURATION

Contents

7.1 Overview

Space Shuttle Vessel uses a mission file to specify vehicle configuration and mission parameters. The mission files are in the JSON format, which allows manual editing, but they can be easily managed with the SSV Mission Editor. After a mission is defined, the Mission Editor can create a pre-launch scenario for that mission.

Mission files are declared as scenario file parameters for SSV vessels, by having the entry "MISSION" followed by the name of the mission file, and must be placed in the directory "<Orbiter installation>\Missions\SSV", or a sub folder.

The SSV installation already has some mission files for the included scenarios.

7.2 Mission Editor

The SSV Mission Editor allows the user to easily create and edit a mission file, and then to create scenarios for them. It is located in the <Orbiter installation>\Utils folder.
The first time the Mission Editor is run it will ask for the location of the orbiter.exe file, so the Mission and Scenario folders can located.
The SSV Mission Editor work flow is as follows: create a new mission or open an existing mission, edit the mission parameters, save the mission file and, if desired, create a pre-launch scenario for that mission.
Several mission parameters aren't implemented yet in the vessels, but are already presented in the Mission Editor as they will be implemented in future versions.
The Mission Editor has the mission parameters grouped into tabs, which are detailed below.

7.2.1 FLT NO tab

Here the user can define the name of the mission, as well as a brief description of it.

7.2.2 ORBITER tab

OV configuration is defined in this tab. Name, texture and basic parameters such as Ku-band antenna can be configured here. Custom OV textures must be located in folder "<Orbiter installation>\Textures\SSV\OV",

7.2.3 CREW MODULE tab

This tab allows the user to define the configuration of the Crew Module.
None of these parameters are currently used, but are planned for a future version.

7.2.4 LAUNCH tab

In this tab the launch site details and launch time can be defined.
The Legacy MECO frame displays the MECO parameters for the mission. They can be manually input here, or calculated in the MECO (Legacy) tab, and then transferred to here.

7.2.5 SSME tab

Here the type of each SSME can be set.
None of these parameters are currently used (the SSMEs are all Block II), but are planned for a future version.

7.2.6 CONSUMABLES tab

OMS, RCS loads for all tanks are defined in this tab. The OMS Kit currently not implemented.
This tab also contains the settings to define the number of PDRS tank sets, EDO Kit and EDO pallets. The Dual EDO Pallet is currently not implemented.

7.2.7 ET/SRB tab

The type and parameters of the ET and SRBs are defined in this tab. In addition, custom textures can be also defined.
Custom ET textures must be located in folder "<Orbiter installation>\Textures\SSV\ET", and custom SRB textures in the folder "<Orbiter installation>\Textures\SSV\SRB".

7.2.8 PAYLOAD tab

The mission payloads are defined in this tab, and are grouped according to type.
For each payload, the user can define the vessel name, class and attachment ID. For each payload location, once the payload name is defined, it will be displayed to the left the controls. In addition, vessel-defined parameters can also be defined (e.g., the payload might have solar panels that are folded during launch).

Active and Passive Payloads

For Active and Passive payloads, latch parameters are available for edit: number, location, orientation and their assignment to control systems, as well as the use of guides. For Active payloads that are not present at launch (e.g., LDEF retrieval), the option exists to not define a payload.

Bay Bridge Payloads

For Bay Bridge payloads, their bay and location is configurable.

Upper Stage Payloads

One "Large Upper Stage" can be selected per mission: the Inertial Upper Stage (IUS), the Centaur G or the Centaur G-Prime. In addition, up to 3 "Small Upper Stages" can be selected per mission: the Payload Assist Module-A (PAM-A), PAM-D and PAM-D2. Currently no "Small Upper Stages" are available, but are planned for a future version. For each upper stage, configuration parameters and payload adapter parameters are also available.

Longeron Sill Payloads

The RMS, or MPM payloads such as the OBSS, are also defined here. RMS SN will only be used for display purposes in SPEC 94 (to be implemented in a future release). Currently the SPDS isn't available, and the RMS can only be on the port side, and payloads on the starboard side (to be implemented in a future release).
The button "Use OBSS" sets the necessary parameters to install the OBSS in the Starboard MPM.

7.2.9 MECO (Legacy) tab

This tab allows the user to calculate MECO parameters to achieve the desired orbit.
More advanced MECO targets (with LAN targeting capability) are planned for the future.

7.2.10 I-LOADs tab

In this tab a list of the currently available I-LOADs is presented. These define various software parameters in the GPCs (e.g., SSME mission throttle setting).

7.2.11 Test Mission

The Test Mission button will run several checks to ensure everything is in order (e.g., each payload latch control system is only assigned to one payload latch).

7.2.12 Create Scenario

This button will open a new window to allow the user to create a scenario for the current mission. Several parameters are provided for editing before scenario generation.

8 FLIGHT DATA FILES

Contents

In this section, checklists are provided for some activities.

8.1 Centaur Deploy Procedures

PANEL AND CISS ACTIVATION

L12U SSP PRI(BKUP) PWR – ON
MECH PRI(BKUP) PWR – ON (mom)
✓MECH PRI(BKUP) PWR tb – gray

PRLA RELEASE

A6U ✓ PL RETEN LAT (five) – OFF
✓ PL SEL – 1
✓ RDY 1,2,3 tb (three) – gray
✓ LAT 1,2,3 tb (three) – LAT

PL RETEN LOGIC PWR SYS 1,2 (two) – ON
R13L BAY MECH PWR SYS 1,2 (two) – ON

A6U PL RETEN LAT 1 – REL (tb LAT,bp)
After approx 30 seconds (60 sec max):
✓ LAT 1 tb – REL
PL RETEN LAT – OFF

A6U PL RETEN LAT 2,3 (two) – REL (tb LAT,bp)
After approx 30 seconds (60 sec max):
✓ LAT 2,3 tb (two) – REL
PL RETEN LAT 2,3 (two) – OFF

PL RETEN LOGIC PWR SYS 1,2 (two) – OFF
R13L BAY MECH PWR SYS 1,2 (two) – OFF

TILT TABLE ELEVATION TO 45º

L12U LOGIC PRI(BKUP) PWR – ON (mom)
DA PRI(BKUP) ROT – UP (mom)
✓DA PRI(BKUP) ROT tb – bp

✓DA PRI(BKUP) ROT tb – gray (after ~5:00)
LOGIC PRI(BKUP) PWR – OFF (mom)

CENTAUR DEPLOY

L12U SUPERZIP* PRI(BKUP) – ARM
✓SUPERZIP* PRI(BKUP) tb – gray

SUPERZIP* PRI(BKUP) – FIRE (mom)

SUPERZIP* PRI(BKUP) – SAFE
✓SUPERZIP* PRI(BKUP) tb – bp

TILT TABLE ELEVATION TO 0º

L12U LOGIC PRI(BKUP) PWR – ON (mom)
DA PRI(BKUP) ROT – DN (mom)
✓DA PRI(BKUP) ROT tb – bp

✓DA PRI(BKUP) ROT tb – gray (after ~5:00)
LOGIC PRI(BKUP) PWR – OFF (mom)

PANEL AND CISS DEACTIVATION

L12U MECH PRI(BKUP) PWR – OFF (mom)
✓MECH PRI(BKUP) PWR tb – bp
SSP PRI(BKUP) PWR – OFF

8.2 IUS Deploy Procedures

9 RELEASE NOTES

Release notes for SSV v1.1

→ The new Vent Door system requires launch scenarios to be generated
→ Rotary Switch Pontentiometer: this new switch type, currently in use in the HUD and MDU brightness switches, rotates clockwise with a left-click on the right-half or the switch, and rotates counterclockwise with a left-click on the left-half of the switch
→ This version corrects swapped port and starboard PRLAs, so PRLAs of existing missions will now show in the opposite side, along with latch systems

10 CHANGE LOG

Changes from SSV v1.0

→ corrected swapped port and starboard PRLAs
→ corrected PRLA connections on STS-8
→ corrected launch pad for STS-8
→ updated and corrected I-LOAD list
→ added missing 'S' in HALS2CPP names
→ corrected misplaced file in release file list
→ updated modification notices
→ removed unneeded modification list
→ deleted redundant subsystem name from scenario generation
→ added countdown time to countdown hold LCC log output
→ added lower click areas for "submerged" switches on panel C3
→ corrected NWS FAIL light drive logic
→ corrected scenario switch positions for RA, OMS, NWS and brakes
→ added information about CRT header function
→ added logic to differentiate PRCS firings from VRCS and play correct sound
→ added VRCS sound to release file list
→ added Rotary Switch Potentiometer
→ updated HUD brightness switches to RotarySwitchPotentiometer
→ moved HUD brightness call to after drawing so avoid lines disappearing when changing brightness
→ added sound to rotation switch
→ replaced MDU brightness step change implementation with continuous change implementation, similar to Rotary Switch Potentiometer
→ added script for COMPOOL address generation
→ added check for repeated variables in COMPOOL
→ added functions to access Integer Double vars in COMPOOL
→ added vent door MCA drive logic
→ added Vent Door Control Sequence
→ added Vent Door Control Sequence interface to SPEC 51
→ added vent door hold check and report to RSLS and LCC
→ improved mechanical systems drive motor and position indication implementation
→ added full path to mission editor in manual
→ added diagram about payload attachments to manual
→ small improvements to manual
→ added D3D9 minimum version information
→ added release notes
→ corrected uv mapping in back of wing
→ improved underside D3D9 bleed in OV textures (moved vent doors to accommodate)
→ simplified layers of OV textures
→ improved HRSI colors of OV102 and 099 tails

11 ACRONYM LIST

ACS	Attitude Control System
APU	Auxiliary Power Unit
BFS	Backup Flight System
CDR	Commander
CISS	Centaur Integrated Support Structure
CRT	Cathode Ray Tube
CT	Crawler Transporter
DAP	Digital Autopilot
DPS	Data Processing System
EE	End Effector
EEC	Extendable Exit Cone
EI	Entry Interface
ET	External Tank
EVA	Extra Vehicular Activity
FCS	Flight Control System
FE	Flight Engineer
FPL	Full Power Level
FRL	Fire Retardant Latex
FWC	Filament Wound Case
GAS	Get Away Special
GEO	Geostationary Orbit
GF	Grapple Fixture
GNC	Guidance, Navigation and Control
GPC	General Purpose Computer
GSO	Geosynchronous Orbit
HPM	High Performance Motor
HUD	Heads-Up Display
IUS	Inertial Upper Stage
LAN	Longitude of Ascending Node
LC	Launch Complex
LCC	Launch Control Center
LDEF	Long Duration Exposure Facility
LEO	Low Earth Orbit
LWT	Light Weight Tank
MCC	Mission Control Center
MDM	Multiplexer/Demultiplexer
MDU	Multifunction Display Unit
MECO	Main Engine Cutoff
MM	Major Mode
MPL	Minimum Power Level
MPM	Manipulator Positioning Mechanism
MPS	Main Propulsion System
MS	Mission Specialist
NWS	Nose Wheel Steering
OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
ODS	Orbiter Docking System
OMS	Orbital Maneuvering System
OV	Orbiter Vehicle
PAM	Payload Assist Module
PASS	Primary Avionics Software System

PBI	Push-Button Indicator
PCR	Payload Changeout Room
PDRS	Payload Deploy and Retrieval System
PFD	Primary Flight Director
PLB	Payload Bay
PLBD	Payload Bay Door
PLT	Pilot
RBUS	Rolling-Beam Umbilical System
RCS	Reaction Control System
RHC	Rotational Hand Controller
RMS	Remote Manipulator System
RPTA	Rudder Pedal Transducer Assembly
RSRM	Redesigned Solid Rocket Motor
SAB	Shuttle Assembly Building
SBTC	Speedbrake/Thrust Controller
SCOM	Shuttle Crew Operations Manual
SILTS	Shuttle Infrared Leeside Temperature Sensing
SLC	Space Launch Complex
SLWT	Super Light Weight Tank
SM	Systems Management
SPM	Standard Performance Motor
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSME	Space Shuttle Main Engine
SSU	Space Shuttle Ultra
SSV	Space Shuttle Vessel
STS	Space Transportation System
SWT	Standard Weight Tank
TAEM	Terminal Area Energy Management
THC	Translational Hand Controller
TAA	Tunnel Adapter Assembly
TPS	Thermal Protection System
VAB	Vehicle Assembly Building
VC	Virtual Cockpit

12 CREDITS

Space Shuttle Vessel is based on revision 3242 of Space Shuttle Ultra (svn://orbiter-radio.co.uk/shuttleultra).

The SSV vessels load JSON files with cJSON library by Dave Gamble and cJSON contributors (https://github.com/DaveGamble/cJSON), included in the code. The Mission Editor loads and saves JSON files with Json.NET by James Newton-King (https://www.newtonsoft.com/json).
Large parts of the launch autopilot were copied (with minor modifications) from PEG MFD.

Some of the attitude control code was derived from Attitude MFD V3.

SSV uses the KOST library.

Vandenberg base uses part of the VandenbergAFB-2006 addon (https://www.orbiter-forum.com/resources/vandenbergafb-2006.3523/) by Usonian.

The SurfaceRoving class is based on the GeneralVehicle addon (https://www.orbiter-forum.com/resources/generalvehicle.3158/) by Fred18.

The file "circuit_breaker.wav" comes from Project Apollo - NASSP (https://github.com/orbiternassp/NASSP).

This addon is open-source and is released under the GNU GPL v2.

DISCLAIMER: The SSV team is not responsible for any crashes or other problems caused by this addon. Use at your own risk.