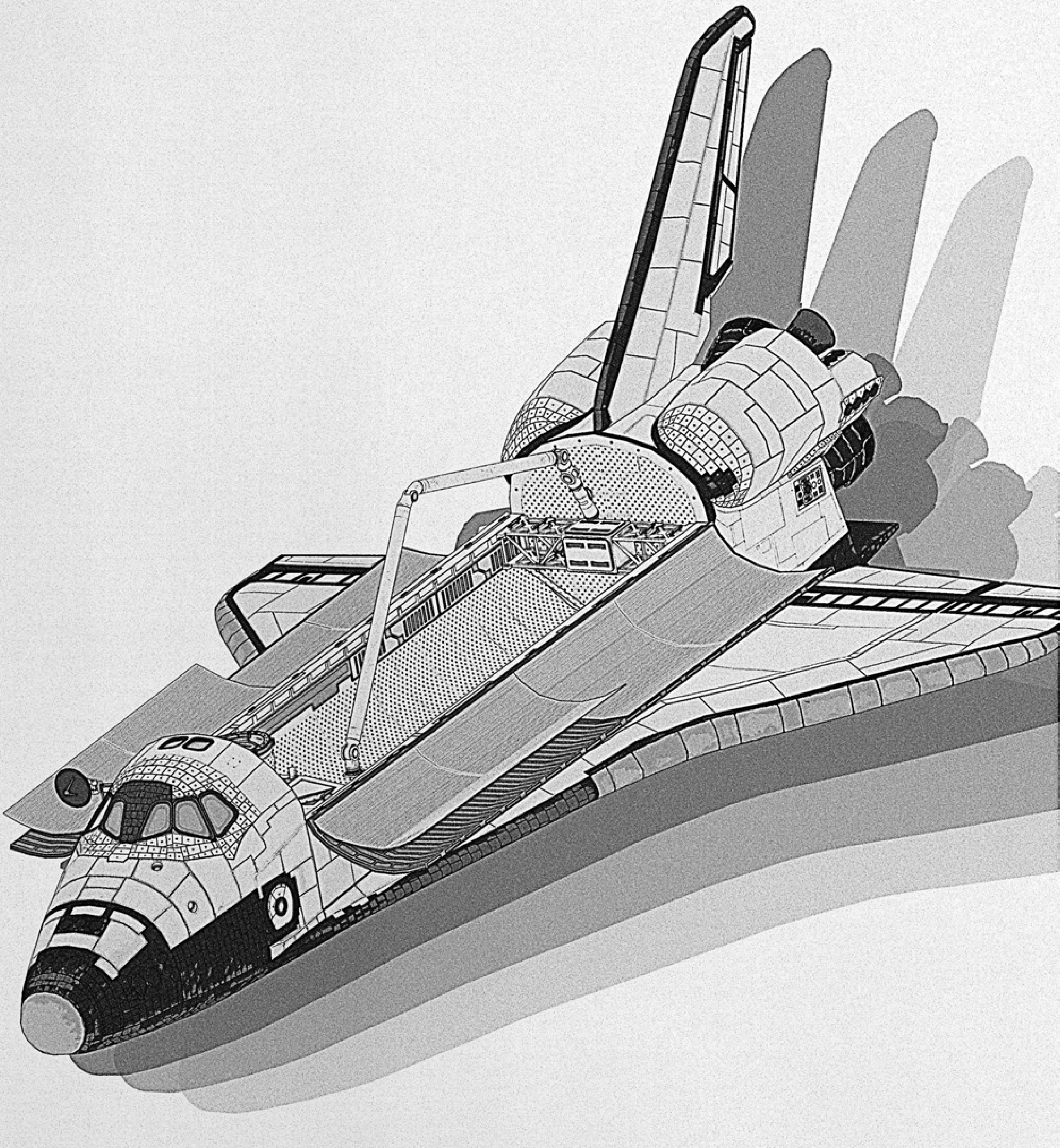
KASA

Kerbal Aeronautics and
Space Administration

Shuttle Orbiter Construction Kit Operations and Assembly Manual

Updated 12th April 1981



Introduction

The Space Shuttle Orbiter is perhaps the most iconic manned spacecraft ever to have flown. This kit of parts is intended to provide a stylised scale replica (roughly 64% the scale of the real Orbiter) for your space program; great care has been taken to ensure that the craft looks, feels and performs like the real thing as much as possible, while retaining the accessibility and ease of use that defines the Kerbal Space Program.

Although the OV-100 Orbiter Vehicle has been designed to be as easy to fly as possible, the nature of the design makes it rather more difficult to construct and fly than a conventional rocket. As such, this operations manual has been put together to provide a suggestion of how to build and fly the Shuttle most effectively. I hope it is of some use to you, and that you are able to fly many successful and exciting missions on board the most advanced and spectacular flying machine of all time.

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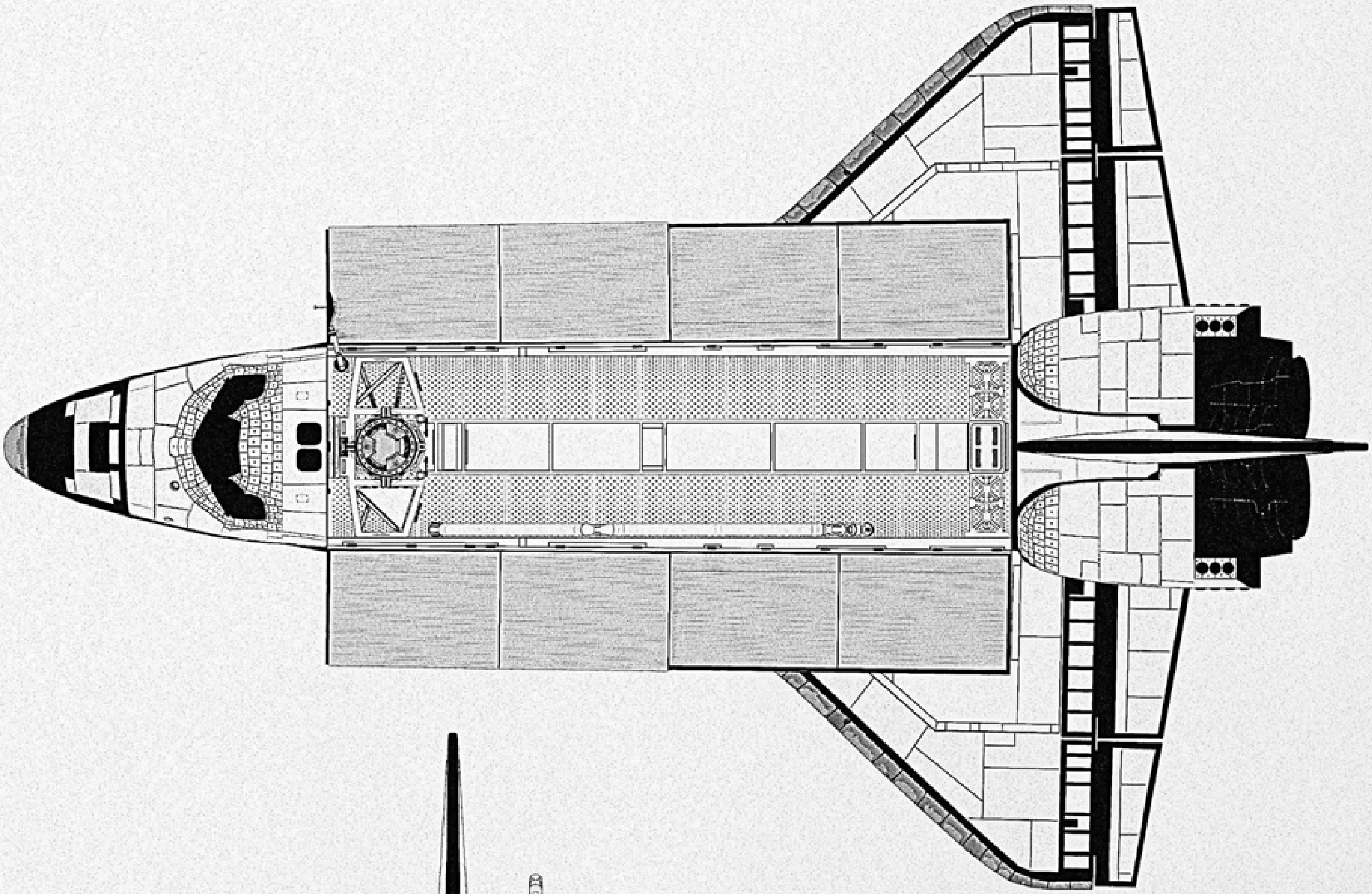
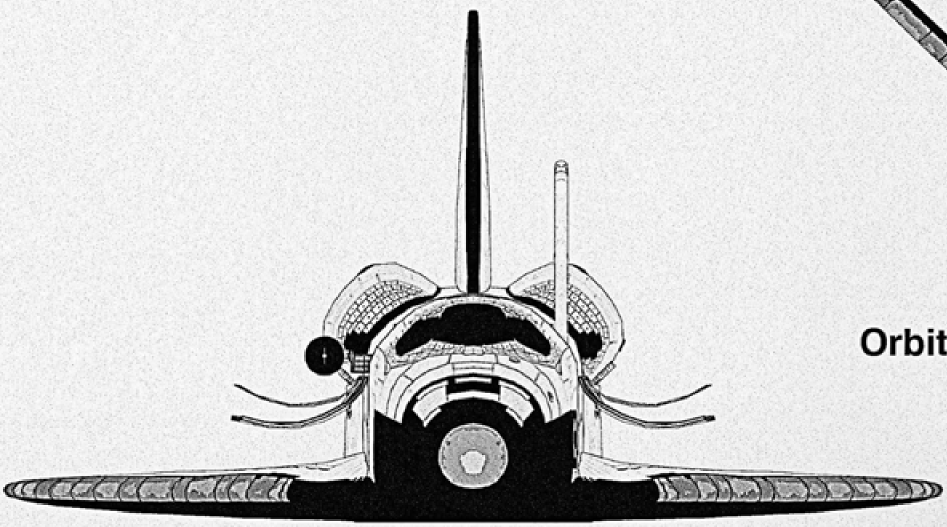
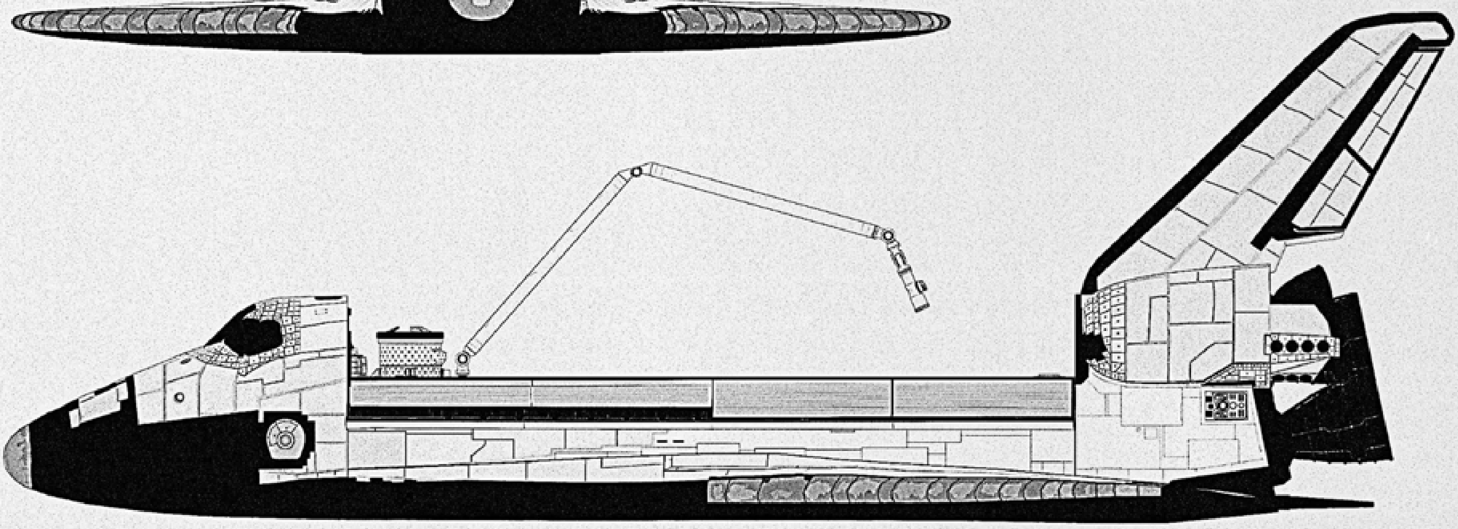




Orbiter Layout Overview



Forward Fuselage

The forward fuselage of the Shuttle Orbiter contains the core pressure vessel that keeps astronaut crews alive. This pressure vessel houses the Flight Deck (through which all Shuttle operations are performed) and the Mid Deck (which provides seating for three additional passengers, as well as stowage and equipment for longer-duration spaceflight, including the vehicle's galley and toilet systems. The aft facing hatch on the Orbiter's Mid Deck provides access either to the payload bay (via EVA) or to an attached docking module.

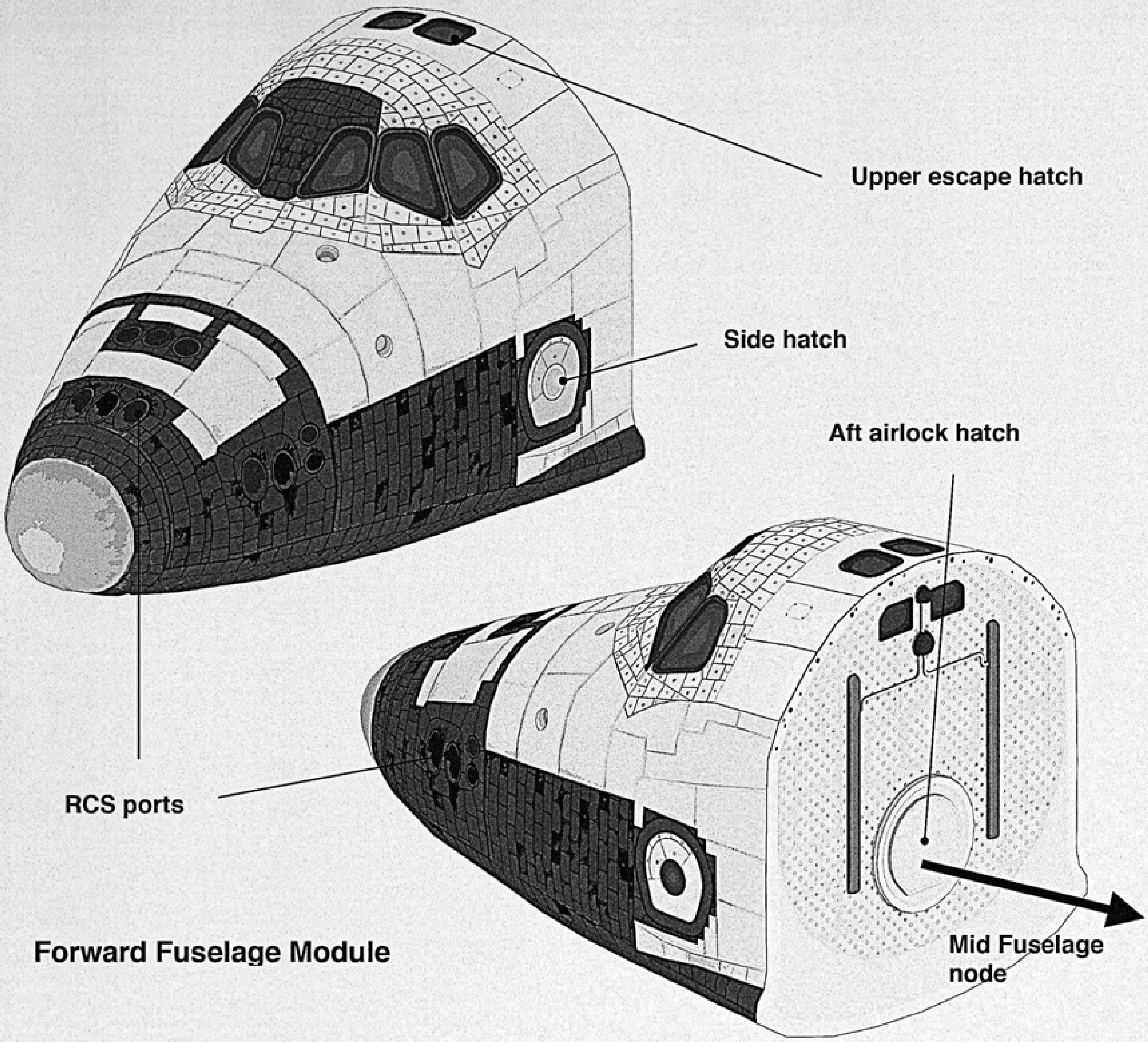
Due to the complexity of the Shuttle, a minimum crew of two is required to operate it.

The forward fuselage contains four sets of integrated RCS thrusters for attitude and translational control. The recommended actuation toggle settings for the four thruster groups is outlined below:

RCS group 1: Fore/Aft translation only
RCS group 2: Pitch & Dorsal/ Ventral
RCS group 3: Pitch, Roll & Dorsal/ Ventral
RCS group 4: Yaw & Port/ Starboard

The forward fuselage features four lockable egress points: the aft airlock hatch (by default), the side hatch (2nd priority) and the upper escape hatch (through the Aft Flight Deck window).

The Forward Fuselage Module also contains a reserve of electric charge, and 200 units of integrated Monopropellant to fuel the forward RCS thrusters.



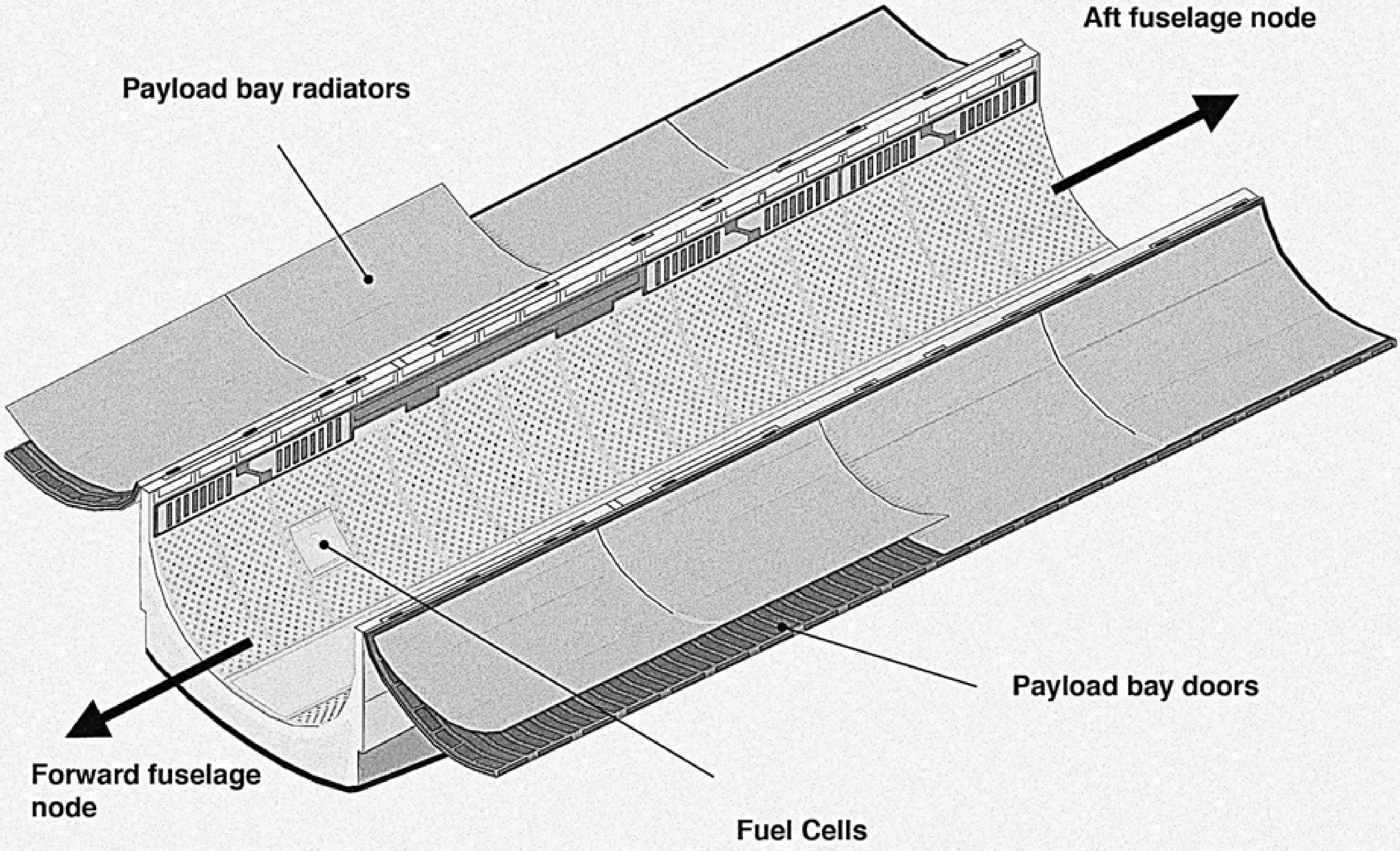
Forward Fuselage Module

Mid Fuselage

The largest structural element of the Orbiter Vehicle is the Mid Fuselage, which forms the structural backbone of the Shuttle. The Mid Fuselage provides an anchor point for the Forward Fuselage, Aft Fuselage & OMS, delta wings, and any payloads/payload bay subsystems.

The Mid Fuselage also contains a set of fuel cells, which provide a constant rate of 1.0 EC/s while activated, suitable for powering the OV's flight. It also contains enough Liquid Fuel & Oxidizer to power the fuel cell for up to 9 days of continuous flight. Additional structural nodes in the floor of the payload bay can be toggled on and off, and a deployment limiter can determine the final angle of the Orbiter's built-in radiator system.

Mid Fuselage Section/Payload Bay



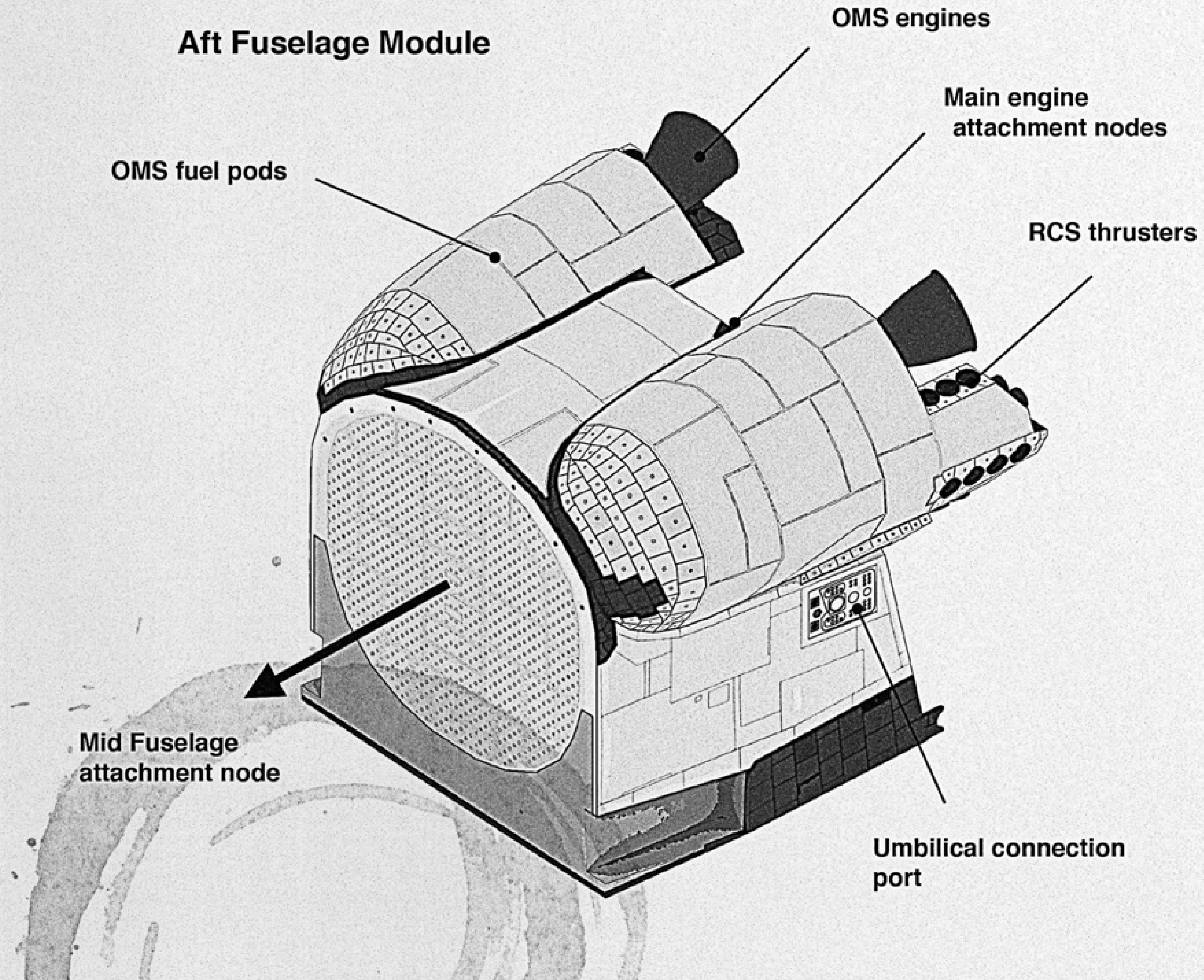
Aft Fuselage

The Aft Fuselage Module is the rear structural element of the Orbiter, onto which the Space Shuttle Main Engines (SSMEs) and Orbital Manoeuvring System (OMS) engines are attached. It also serves as the attachment point for the body flap control surface, the vertical stabiliser/ split-rudder speed brake, anddecouplers/feed lines for external fuel tanks.
The Aft Fuselage also contains integrated Liquid Fuel, Oxidizer and Monopropellant tanks, as well as reserve battery power.

Three integrated groups of RCS thrusters provide attitude and translation control.
Recommended actuation toggle settings are listed below:

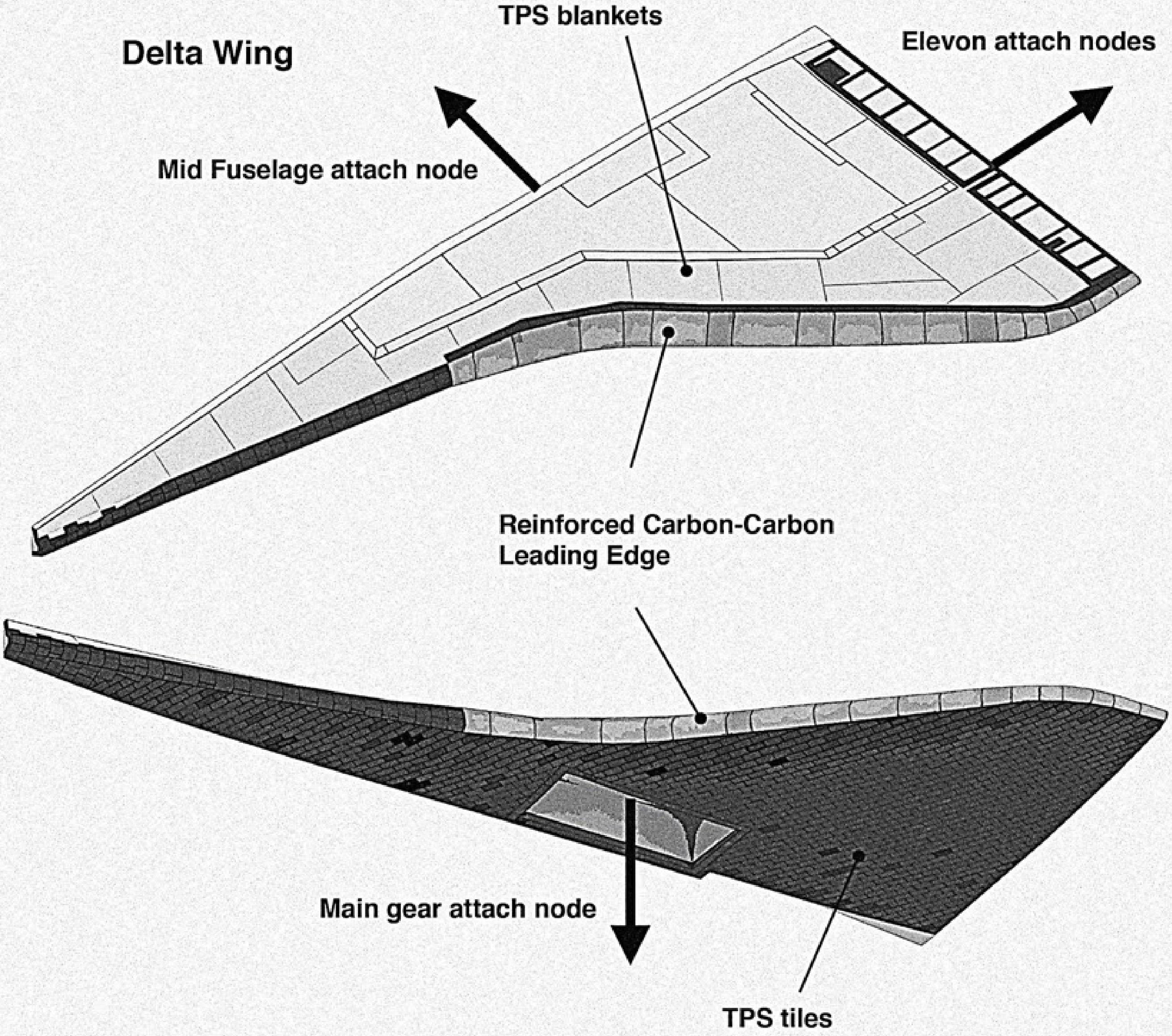
RCS Group 1: Fore/Aft only
RCS Group 2: Pitch, Roll & Dorsal/Ventral
RCS Group 3: Yaw & Port/ Starboard

Aft Fuselage Module



Delta Wings

During atmospheric flight, the Shuttle's two large delta wings provide the majority of the lifting force. It features attachment points for the main landing gear and two control surfaces. The underside of the wing is coated in Silica tiles with a high heat tolerance for protection during re-entry, while the leading edge of the wing is hardened with reinforced carbon-carbon.



Control Surfaces

The Orbiter features five main control surfaces on the horizontal axis: two on each wing (an outer and inner elevon) and one body flap, which juts out behind the Aft Fuselage to protect the engines during entry. The outer elevons should be set to provide roll and pitch control, with the inner elevons and body flap set to control pitch only.

Vertical Stabiliser

The vertical stabiliser connects between the Orbiter's OMS pods and provides yaw control during atmospheric flight - both of the embedded control surfaces should have all actual toggles but yaw disabled. The first integrated control surface should have its deploy direction inverted. When assigned to the "Brakes" Action Group, the two control surfaces will splay out, providing a braking force to slow the Orbiter's airspeed.

Landing Gear

The Space Shuttle uses three landing gear, which are connected to recesses in the lower fuselage. The front gear attaches beneath the nose and is the smaller of the two types, while the larger main gear connects beneath each wing. The gear are protected during reentry by actuating portions of the lower heat shield. For best results, the gear settings should be adjusted manually. The main gear should be set to Spring 3, Damp 2, with 200 brake force, while the nose gear should be set to Spring 3, Damp 2 and 0 brake force.

Propulsion Systems

Orbital Maneuvering System Engines

Two KJ-10 liquid-fuel engines form the Shuttle's OMS, providing thrust for orbital circularisation, on-orbit operations, and deorbit. They are canted out at 15 degrees to point through the Orbiter's centre of mass.

Main Engines

The Space Shuttle Main Engines are attached as a trio to the rear of the Aft Fuselage. Either liquid fuelled engines may be used, or the Hydrolox engines included with reDIRECT (recommended). Angled at 14 degrees from the Orbiter, they point towards the centre of mass and have a high gimbal range to compensate for the shifting weight of the fuel. The engines are fuelled by the massive external tank and will not function once it is disconnected. For maximum stability, the main engines should have their roll actuation toggles disabled.

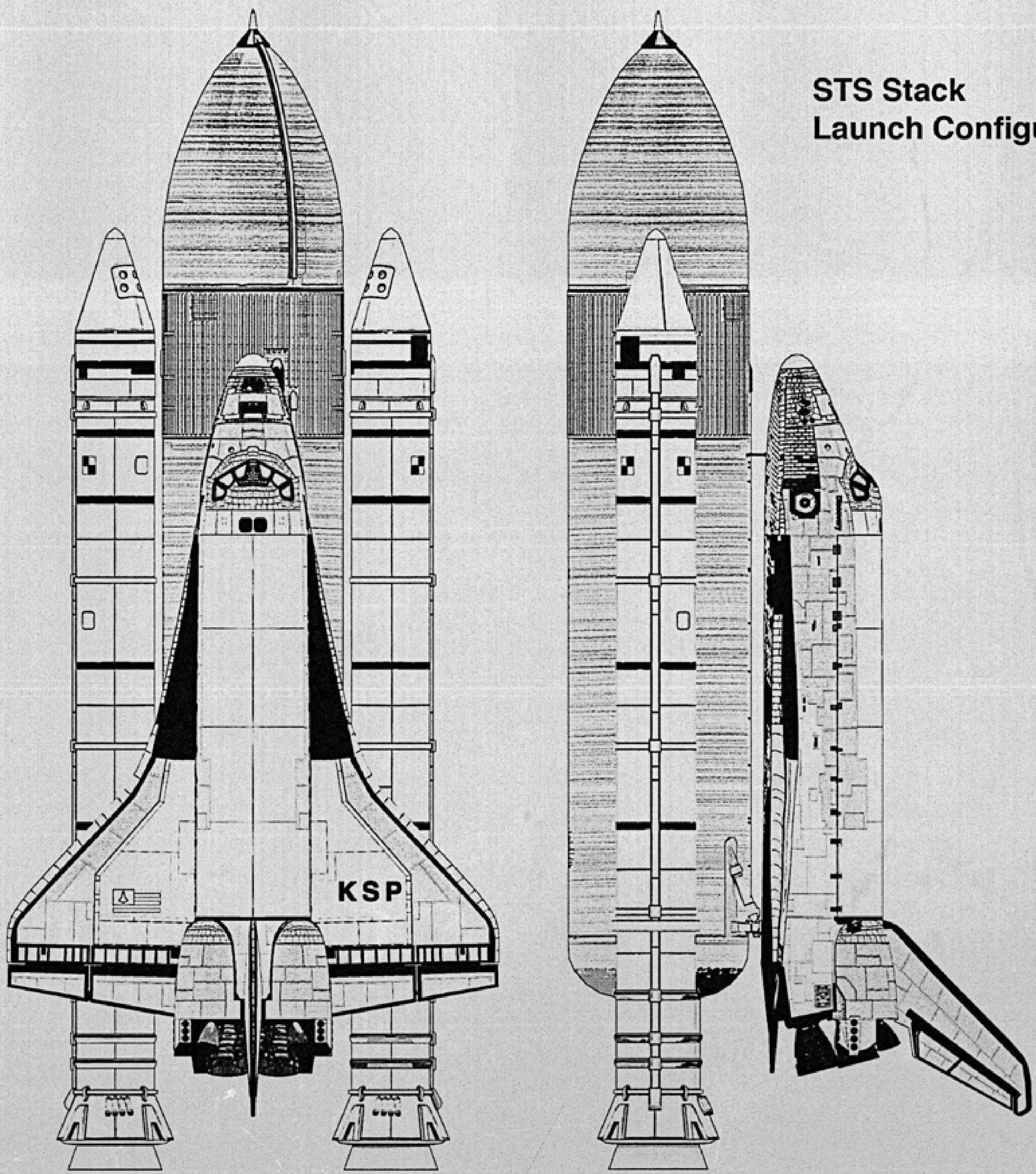
STS Stack

The Orbiter itself is nothing without the ability to reach space; outlined here are schematics for construction of a Space Transportation System (STS) stack making use of 3rd party elements provided by reDIRECT.
Here, the stock KS-25 main engines have been swapped out with KS-25B "Rainstorm" cryogenic engines, which draw fuel from the large S4-JUMBO cryogenic fuel tank through an ET-OV 100-series decoupler. The thrust of the three main engines is not sufficient alone to power the craft at liftoff, necessitating the use of two radially mounted S2 SRB-KD50K "Typhoon" Solid Rocket Boosters, which deliver the thrust necessary to propel the STS stack off the pad at liftoff.

Solid rockets mounted in the nosecone offset at a 45 degree angle from the stack provide a burst of thrust to cleanly the SRBs away from the stack during stage separation.

Finally, the Shuttle's own KJ-10 OMS engines are used to propel the vehicle to its final orbit, as well as perform maneuvers during the mission and the final deorbit burn.

STS Stack
Launch Configuration



Action Groups

Action Groups allow for specific functions of the Orbiter which could not be staged to be triggered with a single button. A proposed set of action groups is outlined below, and is implemented in the provided craft.

Action Group	Function
Launch Action Set	
Action Group 1	Shut down main engines
Abort	Toggle side & escape hatch locks
Orbit Action Set	
Action Group 1	Toggle payload bay doors
Action Group 2	Toggle Ku-band antenna
Action Group 3	Activate fuel cell
Action Group 4	Toggle OMS engines
Action Group 0	Toggle robotics joint locks
Abort	Undock ODS
Landing Action Set	
Brakes	Toggle split-rudder speed brake

Construction Procedure

Process control element 1: Remove PARTs (Pre-Assembled Reference Tranches) from the KSPPAM (Kerbal Space Program Part Access Menu) and place on the NODEs (Nodule Oriented Deposition Endpoint) sequentially according to earlier parts of the manual, until Orbiter construction is complete.

Process control element 2: Maintain contact with high bay vehicle personnel in compliance with SAVE (Service After Vehicle Erection) regulations to ensure proper documentation and handling of vehicle construction. Failure to comply regularly with SAVE regulations may result in Loss of Vehicle accidents in the event of data loss.

Process control element 3: After stack assembly has been completed with appropriate SAVE documentation and PART quality traceability reports, process control of the Orbiter will be passed from high bay assembly personnel to STRUT (Structural and Transitional Regimes Unified Technicians) for a structural analysis and test of the full stack, where the full results shall be codified in an autoSTRUT document.

Process control element 4: After STRUT operations conclude, software and program consulting will be taken over by The Action Group, tailored to the specific STS mission. Deliverables for this phase of the launch campaign will be mission software and crew training for use of said mission-specific software. The conclusion of this element will pass program control back to the Vehicle Assembly Building throughout the final phases of the launch campaign.

Process control element 5: Final staging operations and checkouts are to be conducted in the high bay, most importantly a sequence check of all engine, decoupling, and mechanical deployment events in compliance with SAVE protocols. The results of this final inspection will be compiled into a Manley report for review by crew and administration before rollout. Review of the Manley report is also to be conducted on the pad to prevent avoidable Loss of Crew and Vehicle events.

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OF POOR QUALITY

SSRMS ('KerboArm')

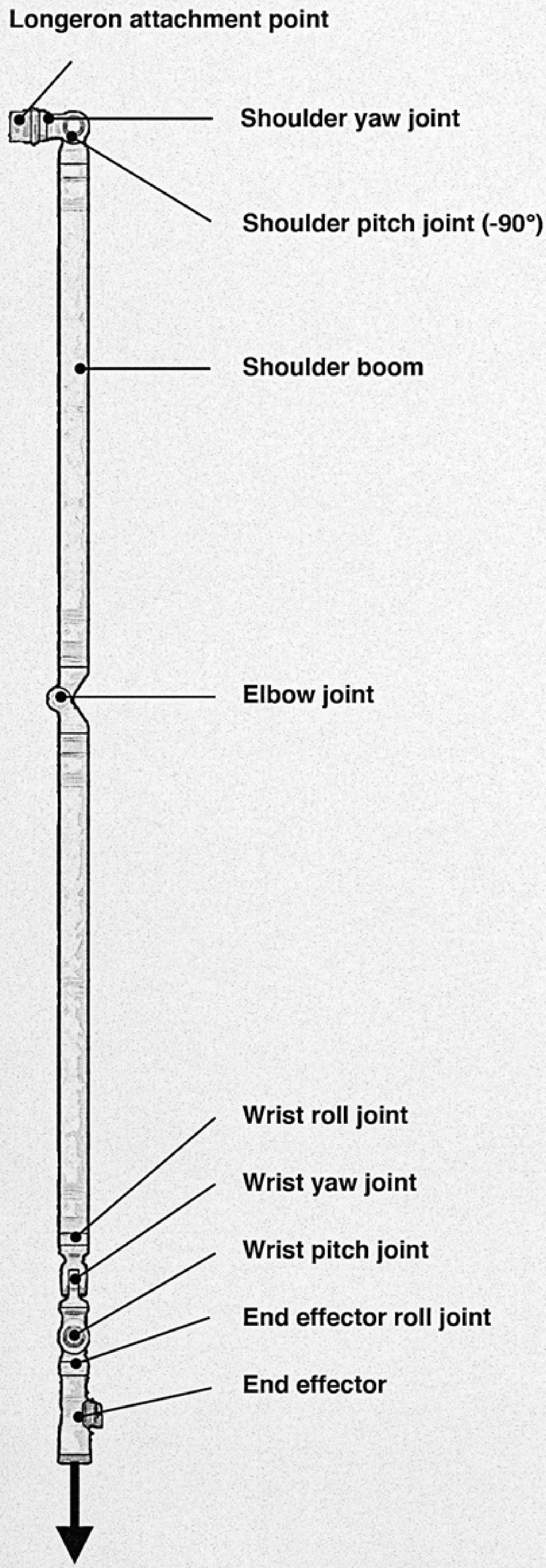
The Space Shuttle Remote Manipulator System (SSRMS), colloquially referred to as the 'KerboArm', provides the ability to manipulate heavy or otherwise unwieldy payloads and satellites when on orbit.

The SSRMS can be controlled by two different systems; the Breaking Ground Integrated Robotics System, or the Infernal Robotics Control System. If IR is installed it will override the default Breaking Ground robotic controls, however this can cause compatibility issues between arms constructed with BG active and arms constructed with IR active. Active Shuttles should be deorbited and their arms rebuilt before a change in control scheme is made.

Structurally, the arm is divided into three main sections: the shoulder, elbow, and wrist/end effector. The should joint connects to the Shuttle's payload bay via a Longeron Attachment Point, which can be attached radially to the payload bay walls and offset as necessary. Onto this is attached a 360° rotational servo (forming the yaw joint), and then a servo pitch joint. In order to be stowed in the bay, the pitch joint should be rotated to the -90° position. From here, a standard boom is attached followed by the KerboArm elbow joint, which has an offset centre of rotation and is capable of bending 180° back on itself. A second boom connects the elbow to a second 360° servo, which is then sequentially attached to two more pitch joints, the first of which is offset on the roll axis by 90° to provide yaw control for the wrist. A third 360° servo provides roll for the end effector, which is the final part to be attached. The silver cone of the end effector's camera should be pointing aft away from the shoulder.

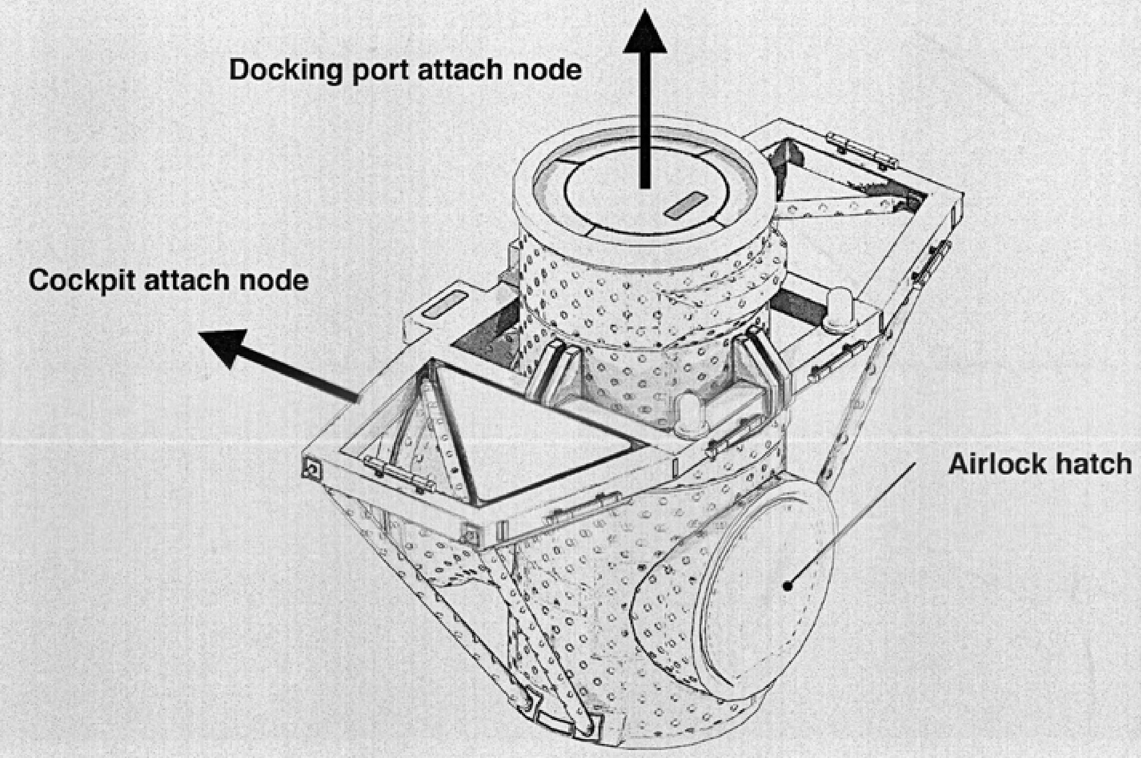
The Latching End Effector works like a traditional docking port, but can only connect to Power Data Grapple Fixture. The end effector can only connect successfully in increments of 120°.

For maximum stability, very low torque and traverse sates are recommended. An autostrut to root part should be placed on the end effector, allowing the arm to be fixed in place when the joints are locked. This prevents the arm from swinging wildly inside the payload bay during maneuvers.



Orbiter Docking System (ODS)

The Orbiter Docking System provides a mounting point for a 0.9375m docking port facing ventrally out of the Orbiter's Payload Bay in an ideal location for docking. It also features a hatch for EVA capabilities, since the ODS attaches over the Shuttle's integrated airlock hatch. The ODS can house two crew members at a time.



Payload Structural Elements

Currently, the Shuttle is provided with a truss section which attaches to the toggleable nodes on the floor of the payload bay, and provides three attachment nodes for payloads, facing fore, aft and ventrally from the Payload Bay.

Ku-band Antenna

The Ku-band antenna attaches to a longeron attachment point, much like the KerboArm, and provides communications capabilities to the Shuttle.

Department of Defence Payload Integration

[redacted]

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Control Systems

Although the Space Shuttle as designed is intended to be as stable and simple to fly as possible at all times, the Shuttle's profile is inherently difficult to control (especially on ascent) due to the asymmetric nature of the stack and the dynamic conditions of launch. As such, although manual control is possible, it is recommended to fly with a number of control system modifications added. These are detailed below.

MechJeb 2.0

MechJeb 2 provides a suite of control systems which make piloting the Space Shuttle at launch extremely simple and repeatable. The Ascent Guidance Computer handles the Shuttle's launch profile extremely well, and the SMART ASS module is capable of maintaining the vehicle's heading during launch and re-entry. The ability to lock the Orbiter's pitch, yaw and roll to a specific angle in multiple frames of reference greatly reduces the complexity of docking maneuvers as it removes the need to adjust attitude as well as translation.

Ascent Guidance
Primer Vector Guidance allows for an efficient launch with no coast phase or circularisation burn. The guidance computer should be set to aim for a 300km x 100km orbit, with a pitch rate of 0.6°. Roll should be forced and initially locked to 180°.

SMART A.S.S.
SMART A.S.S. provides precise attitude control, and is much stronger than that available in stock guidance systems. This is invaluable on a vehicle like the Shuttle, which is subjected to large and rapidly changing rotational forces. In some cases, stock guidance will be unable to hold an attitude, whereas SMART A.S.S. will have no problem.

Landing Guidance
While MechJeb 2's landing guidance is not entirely applicable to landing the Shuttle, it does offer a useful trajectory prediction feature, the use of which is detailed under 'Flight Profile: Deorbit.'

Atmospheric Autopilot

Atmospheric Autopilot provides a much smoother control model for the Shuttle during the final approach and landing phases. When activated, it overrides all other control modes (including MechJeb) and smooths out the binary keystroke input for a stabler flight experience. This also benefits users who fly with a joystick/HOTAS.

Infernal Robotics - Next

By default, the Space Shuttle's robotic systems use the Breaking Ground DLC's robotics modules to function. However, if this DLC is not owned or the Infernal Robotics - Next integration is preferred, the robotics will automatically configure themselves to use IR - Next if it is installed.
Caution should be exercised when installing/uninstalling IR - Next, as switching between the new systems can cause problems with existing craft that are in flight. An appropriate craft file should be selected, and existing vessels using the robotics should be deorbited and recovered before the installation occurs. Craft constructed while using the other robotics modules should have their robotic elements removed and rebuilt in the VAB before launching in order to avoid unexpected issues.

Flight Profile

Overview

The Space Shuttle is designed to carry both a crew and a moderate payload to a low orbit around Kerbin, operating at altitudes between 100km and 600km. To a standard operating orbit of 350km x 350km, the Shuttle can carry up to 15t of payload. On orbit, the Orbiter functions as a mobile workstation, utilising a large payload bay, robotic manipulators and multiple attachment points to facilitate a wide variety of mission types, including but not limited to station construction, resupply, reboost, satellite deployment, on-orbit repair, crew rotation, scientific experimentation, and payload retrieval. Once a mission is complete, the Orbiter is able to glide softly to a runway landing.

NOTE: These numbers and the following guidelines are based on a 2.5x stock scale Kerbin or home planet. The Shuttle will have significantly higher capabilities at 1x scale.

Space Shuttle OV-100 Orbiter Vehicle - Critical Data	
Length	21.6m
Height	8.6m
Wingspan	13.7m
Mass (dry)	20.195t
Mass (wet)	25.995t
Minimum crew	2
Maximum crew	7
Baseline operating altitude	350km
Maximum operating altitude	600km
Maximum payload volume	2.6m x 2.6m x 10.6m
Maximum payload mass*	15t
Maximum downmass	10t
DeltaV (no payload)	512m/s
DeltaV (max payload)	321m/s
Maximum time on orbit	9 days

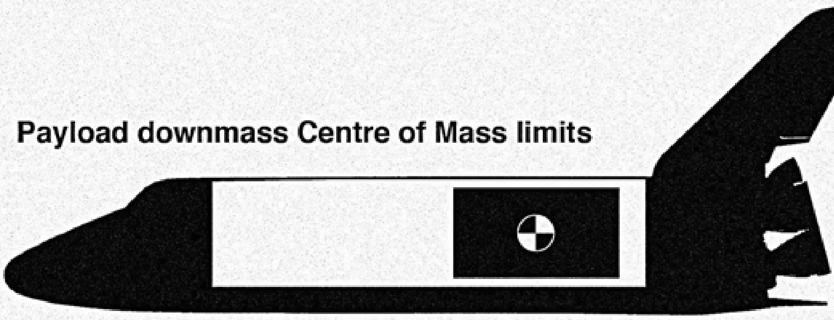
**Assumes payload delivered to baseline operating altitude*

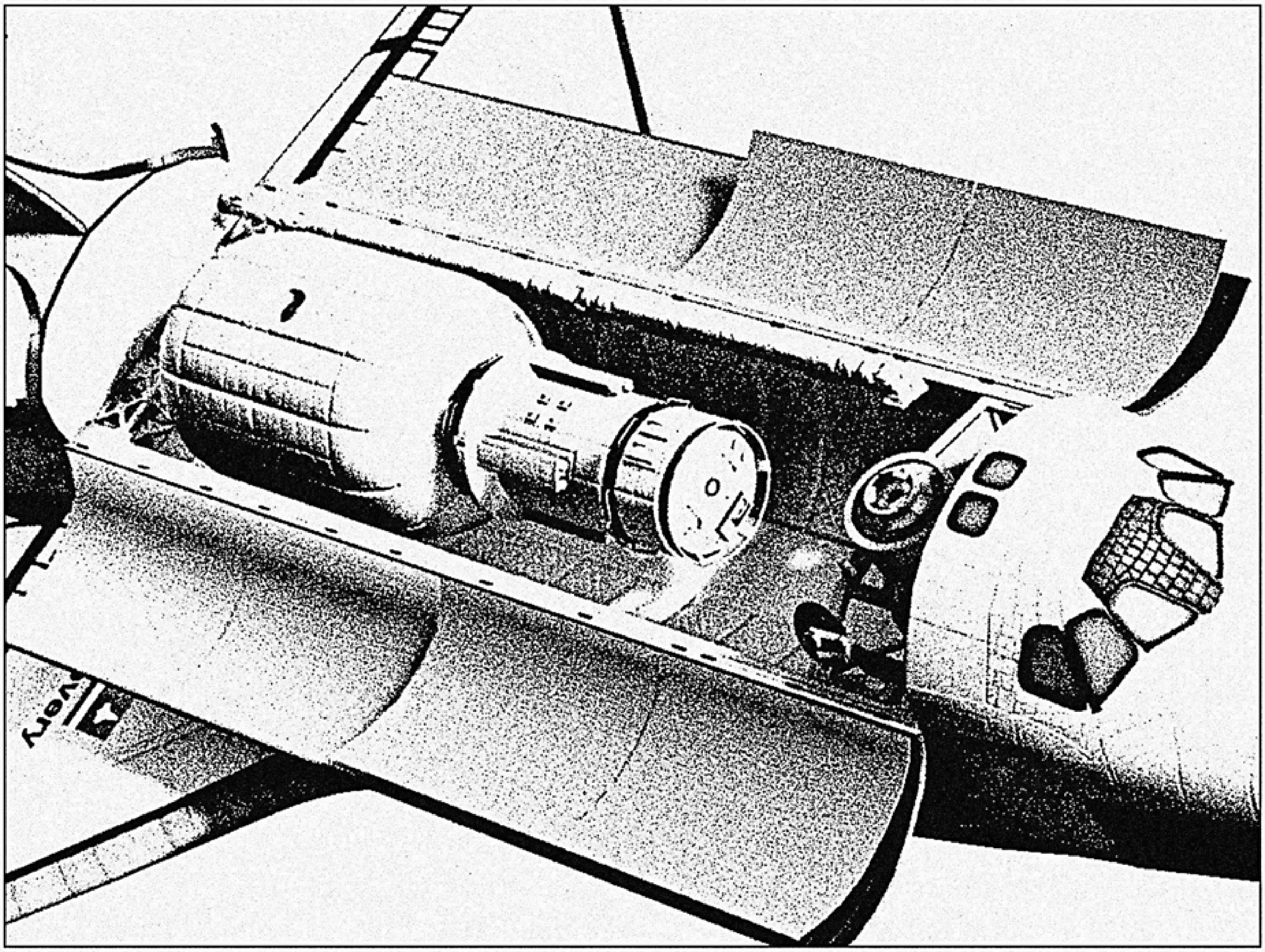
Payload Integration

While payload placement during launch generally will not affect the stability of the Shuttle during descent, care should be taken to ensure that the payload is placed such that the Shuttle will be able to land with the payload in place in the case of an emergency abort. The diagram below shows the bounding box into which the payload centre of mass must fit in order to retain sufficient control of the vehicle during landing. This limit can be exceeded, however, it will prevent the intact recovery of the Orbiter during an abort during the launch phase of flight. In this case, a crew bailout procedure must be followed, allowing the vehicle to safely be destroyed in the ocean.

These bounding box limits also apply to down mass, and thus places a limiting factor on the shape and mass of payloads that can be recovered from space using the Shuttle Orbiter's payload bay. This restriction is particularly important here as a returning Orbiter will have significantly less fuel in the Aft Fuselage than one on launch, meaning the centre of mass will naturally be placed further forwards.

Payload downmass Centre of Mass limits

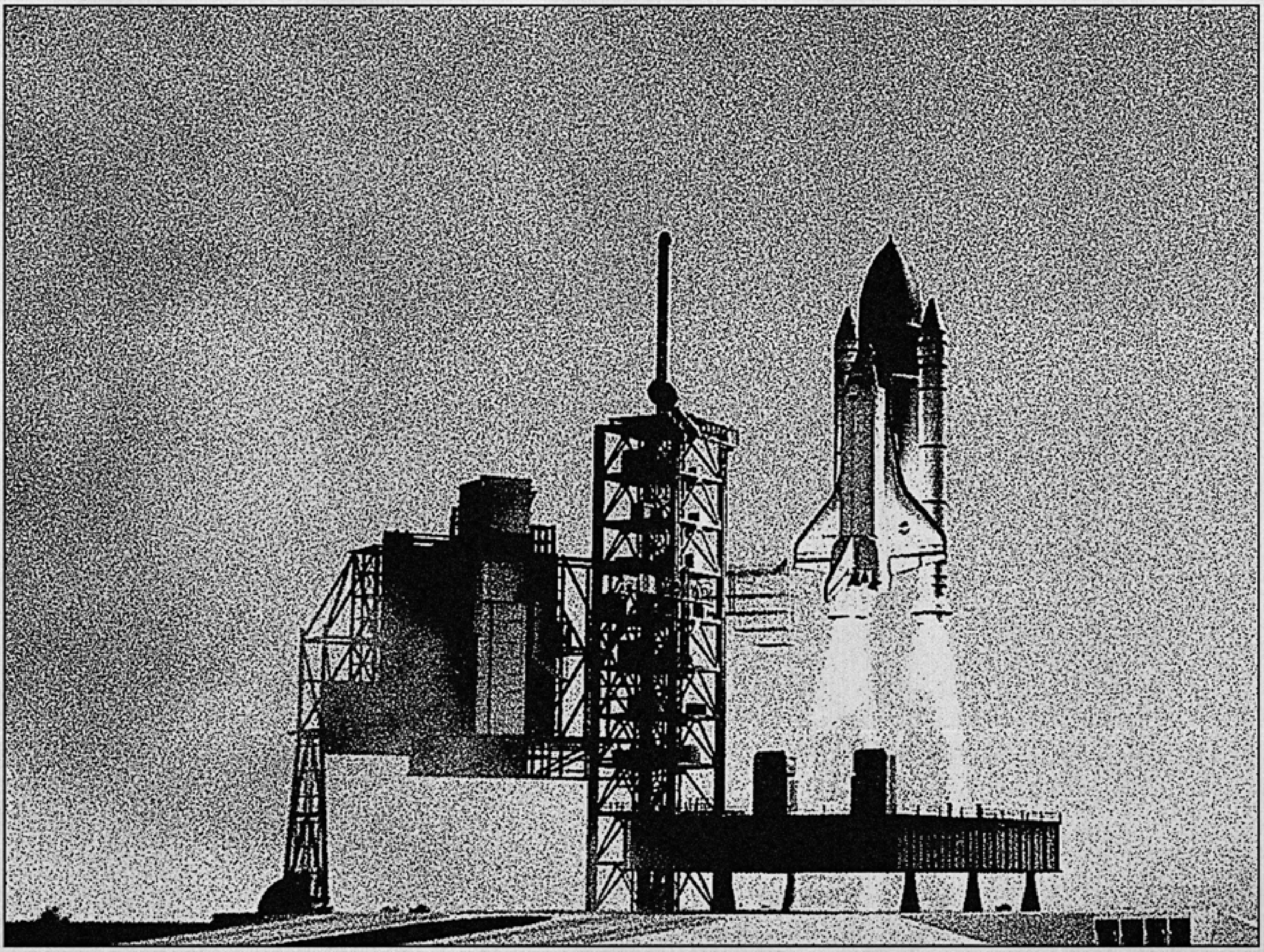




Launch

Key events (timings are approximate):

T-00:00:06 - Main engine start
T-00:00:00 - SRB ignition - liftoff
T+00:00:04 - Roll program
T+00:00:10 - Pitch program
T+00:00:35 - Main engines throttle down to 33%
T+00:00:58 - Main engines throttle back up to full power
T+00:02:05 - SRB separation
T+00:02:30 - Roll to heads up
T+00:04:00 - Main Engine Cutoff (MECO) - AP: 300km PE: 100km
T+00:05:00 - External tank separation
T+00:30:00 - OMS-1 - AP: 350km PE: 300km
T+01:00:00 - OMS-2 - AP: 350km PE: 350km



Prior to liftoff, the Shuttle must be prepared for flight, readying it for either manual or automatic control. Using Primer Vector Guidance, the target apoapsis, periapsis and inclination should be set. The recommended settings here are AP: 300km, PE: 100km, INCL: 0°.

To launch for rendezvous on an inclined orbit, the inclination should be matched to that of the target object. Force roll should be set to true and to 180° on climb and turn. Pitch rate should be set to 0.6. Limit Q should be turned on, with the minimum limited throttle set to 33%.

If using 1.7.1, the Action Group "0" should be used to lock the robot arm in place (if installed), or in 1.7.2 locked prior to rollout in the editor. The Action Set should be changed from 'Default' to 'Launch' mode.

If launching to a target on an inclined orbit, the launch should be timed such that the space centre passes directly below the orbit of the target object. At T-6 seconds, the throttle should be set to 100% and the first stage activated, igniting the main engines. At T-2, activate SAS. At T-0, either stage a second time to ignite the SRBs and release launch clamps, or activate the ascent autopilot, which will automatically stage again.

At T+4, the Shuttle should be rolled into the 'heads down' position, with the cockpit upside down relative to the direction of flight. It should then at T+10 begin to pitch over, with the Orbiter itself hanging below the external tank. It should be at approximately 10 degrees during this portion of the flight, guiding the shuttle out past the KSC towards the ocean.

At T+35, the main engines should gradually be throttled down to 33% to reduce structural loads in the area of maximum dynamic pressure. They should remain this way until T+58 seconds, at which point they should be throttled back up. During this time, the spacecraft should be gradually pitched over at around half a degree per second, matching the Shuttle's ascent rate until it is parallel to the ground at around 60km up.

At T+2m4s, the SRBs will run out of fuel and should be jettisoned. After this, the shuttle cockpit's control point should be set to -15°, aligning the control direction with the direction of thrust. At T+2m30s, the roll angle should be set to 0°, gently rolling the vehicle to the 'heads up position'. The Shuttle's path with guide it up above the atmosphere. The pitch angle should be gently adjusted to bring the periapsis out of the ground up to the target altitude. MECO should occur around T+4m. Action Group "1" will shutdown the main engines. Unless operating an extremely heavy payload, it is normal for MECO to occur with a few hundred m/s of Delta V in the External Tank.

At this point, the Reaction Control System should be toggled on, along with fine control mode. With the vehicle stable, a plus Y axis translation should be commenced alongside staging to clear the Shuttle Orbiter from the External Tank.

Orbital Operations

Following separation from the ET, the Orbiter Vehicle should be placed into 'Orbit' mode. This disables a number of systems required for launch, and enables a number of systems required for orbital flight.

Firstly, the Action Group "1" becomes assigned to opening/ closing the payload bay doors. Action Group "2" extends and retracts the Ku-band antenna. Action Group "3" activates the Orbiter's fuel cell, providing power. Action Group "4" toggles activation of the OMS engines. Action Group "0" will lock and unlock joints in the SSRMS 'KerboArm' if installed. Finally, the "Abort" group becomes assigned to the Orbiter Docking System if installed, allowing the Orbiter to rapidly undock from a station if an emergency occurs. Further customisation of the Action Groups based on payload-specific conditions should be performed in the Vehicle Assembly Building (VAB) prior to rollout and launch.

The Shuttle Orbiter's fuel cell is located in the Mid Fuselage and is rated to provide 1.5 EC/S by reacting Liquid Fuel and Oxidizer. The fuel cell can provide constant power for approximately 9 days on orbit, although use of robotics, manoeuvring, and certain payload operations can result in a reduction to this number. Due to this, a safe mission length is considered to be 7 days.

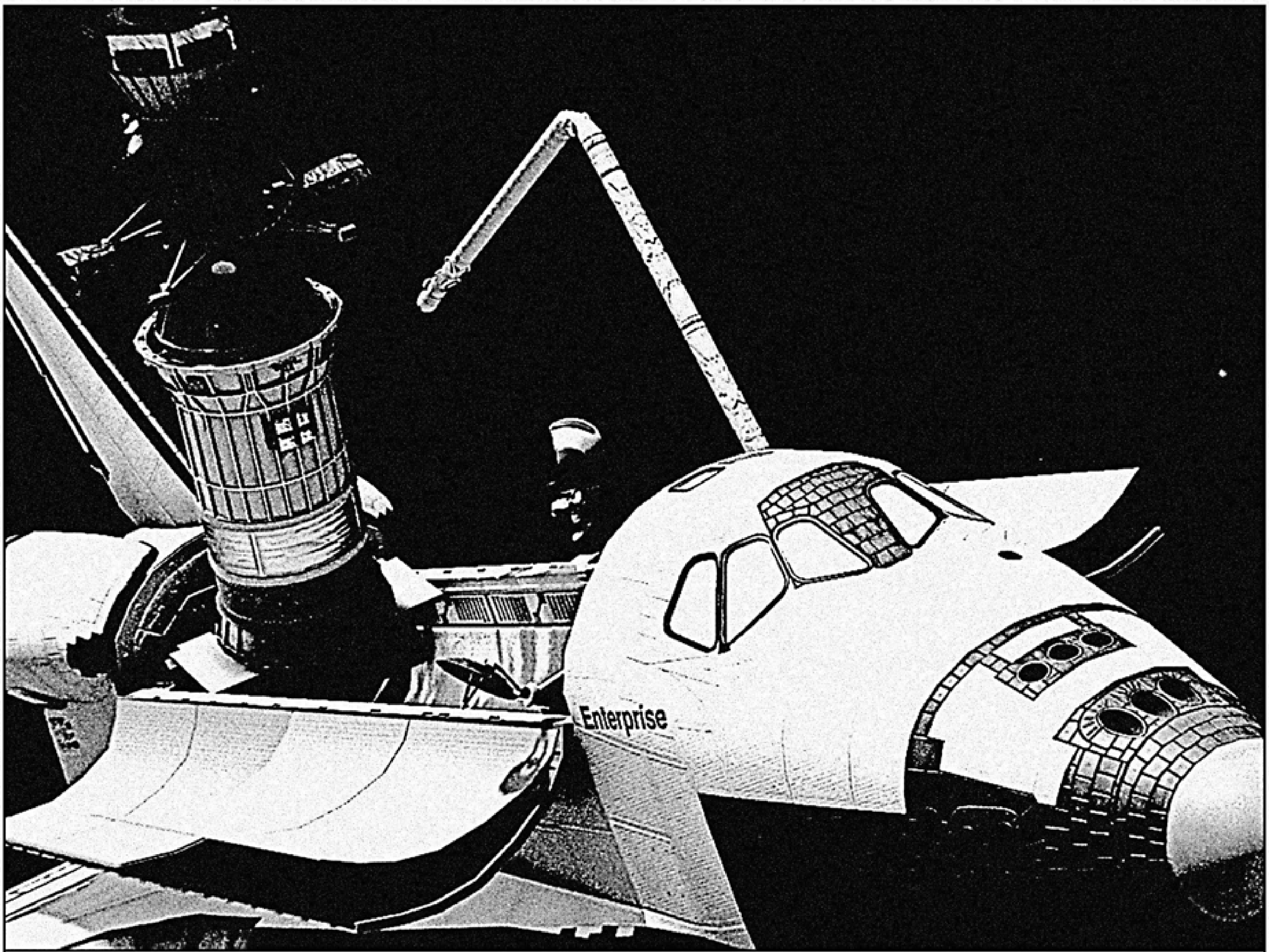
Rendezvous & Docking

Rendezvous is performed as it would be with any other orbital craft, with the Shuttle moving to a phasing orbit that is either higher or lower than the target in order to move to an optimal position for performing a Hohmann transfer to the target. The Shuttle's standard parking orbit of 350km x 350km makes a good phasing orbit for targets in the 400km+ orbital range.

A Hohmann transfer should aim to place the closest approach with the target within the 2.5km range. It is recommended that for station rendezvous the Shuttle's orbit always remains lower than that of the station, as this allows the Orbiter to approach from the nadir (planet facing) side, making imaging the Shuttle's TPS easy and allowing orbital mechanics to naturally slow the two vessels, preventing potential collisions. From the 2.5km mark, velocity can be matched and repeated sequences of small OMS burns place the Orbiter at closer and closer range to the rendezvous target.

Once within around 150m, docking operations can begin. Due to the nature of the Shuttles RCS thruster layout & setup, it is recommended to retain the Forward Fuselage as the control point, as controlling from the ODS APAS unit may result in unexpected thruster firings. The Forward Fuselage control point should also be reset to default. Fine control mode is especially helpful during docking as it balances the RCS thruster firings around the centre of mass, helping to prevent unwanted torque.

MechJeb 2.0's SMART A.S.S. feature can be used to hold the Shuttle and the docking target at a fixed attitude. Common attitudes include the Shuttle facing nose-up,



The KerboArm is used to assist in the deployment of a satellite propelled by a Bluedog Design Bureau Inertial Upper Stage.

with the docking port oriented along the orbital prograde vector, or the Shuttle facing nose-back, with the docking port oriented along the radial out vector. The docking target should then be placed in a corresponding attitude, with the targeted docking port rotated 180° to the Shuttle's APAS port.
With attitude being held by the Shuttle's flight control system, it is then a relatively simple matter to use the translation controls to move the vehicle towards the docking port. Care should be taken not to accelerate the Orbiter to too high a velocity - its large mass and relatively low thruster power makes it difficult to slow down quickly. Care should be taken to avoid thruster firings in the direction of the station - instead, allow orbital mechanics to naturally brake the two craft as they approach one another. Once the two docking ports are in range, a magnetic force will pull them together for final docking.

Deorbit & Reentry

De-orbiting the Shuttle Orbiter in order to achieve a safe landing is no easy task, and is one that requires a great deal of skill and practice, especially when attempting a return from a non-equatorial orbit. In principle, this process is relatively simple, requiring the Orbiter to be rotated to point along the orbit's retrograde vector, and a small burn of the OMS to be performed, thus lowering the Shuttle's orbital velocity enough so that it drops into the atmosphere. From there, atmospheric drag decreases the Shuttle's speed yet further, bringing it lower in altitude until the craft's aerodynamics take over.
From a standard operating orbit of 350km x 350km at 0º inclination, a typical deorbit burn is around 160m/s. Deorbit should only be performed after the Shuttle's SSRMS and Ku-band antenna have been stowed, and the payload bay doors have successfully been closed. The burn should be performed at an appropriate time such that the periapsis (low point) of the vehicle's orbit is approximately 22km, and roughly 45° around the planet from the KSC, above the shoreline of the next continent to the East. If using MechJeb's landing predictions, the predicted touchdown point should be placed over the mountains to

the West of the KSC. Returning from an inclined orbit, the target should be placed in an equivalent position rotated from the KSC In the direction of travel. In order to compensate for the rotation of the planet, it should also be placed slightly ahead of the position it normally would be from a 0° orbit.

As the Shuttle approaches the atmosphere, it should be placed at a roughly 30° AoA and control point reset to forwards. As the atmosphere begins to slow it down, this angle of attack can be modulated in order to maintain a trajectory that reaches the KSC. Roll can be applied to modify the Shuttle's lateral velocity and avoid too great an increase in vertical speed, with the vehicle performing long S-curves to reduce velocity without increasing altitude or affecting the trajectory too greatly. As the vehicle drops further, the AoA can be decreased greatly to maintain velocity and ensure the Orbiter has enough energy to reach the KSC. If the AoA is too high, it will stall out and drop on a ballistic trajectory, falling short of the runway.

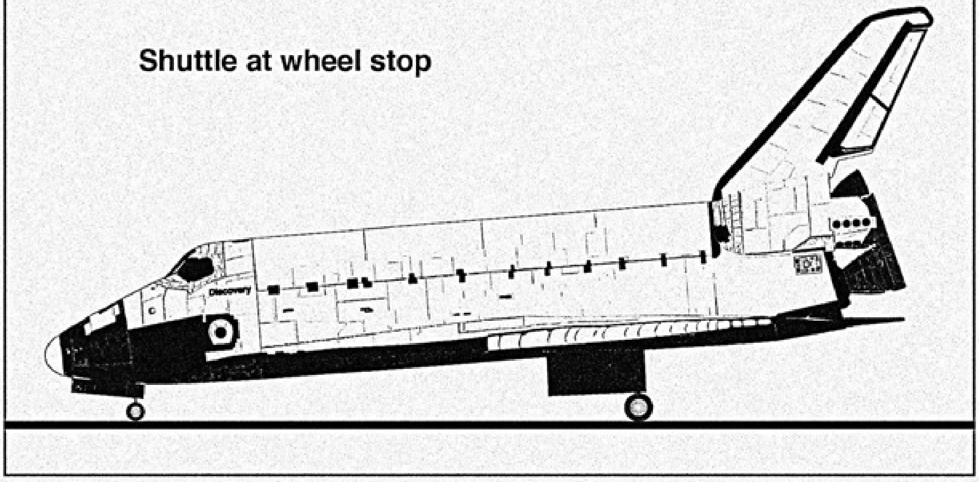
As the KSC comes into sight, the Orbiter should be travelling at around 1700m/s. From this point, the Action Group Set should be switched to "Landing," allowing the split-rudder speed brake to function. If installed, Atmospheric Autopilot should be activated here in order to provide finer control over the vehicle through approach and final descent. Banking movements should be used to align the vessel with the runway.

Landing

Although the Shuttle Orbiter appears to be rather aerodynamic, it lacks any power during atmospheric flight and must perform final descent as a glider. As such, energy management is critical; the Orbiter's lift-to-drag ratio is so low that a go-around is impossible.

From around 10km in altitude, the pilot should pitch the nose of the Orbiter down, aiming the vehicle's trajectory so that is is accelerating towards the ground at around a 35° angle, with the point of impact placed 300m ahead of the runway's start. At this point any final heading correction maneuvers should be performed. By making use of the speed brake and small shifts in pitch, surface velocity should be kept between 150-200m/s.
By 2km in altitude, a gradual pitch up should be performed, beginning to slow the shuttle down. At 300m, a pitch maneuver should be performed, bringing the nose up to +10° and cutting greatly reducing vertical speed. Pitch should then be adjusted to keep the vertical speed as low as possible, gently dropping the vehicle's main gear onto the runway. With the speed brake and normal gear breaks applied, the shuttle should naturally rotate down into a landed position, dropping the nose gear onto the runway.

Shuttle at wheel stop



Abort Modes

Although the Shuttle Orbiter is designed to be as reliable as possible, accidents in space travel are unavoidable. The following pages detail contingency plans should the primary mission of the Shuttle become compromised. Primary concern is preventing Loss of Crew (LoC), with a secondary concern being preservation of the OV itself.

Early Flight Abort

Due to the nature of the Shuttle's early flight program (from T+0 until the separation of the Solid Rocket Boosters), a mechanical abort during this time frame is impossible. If at all possible, it is recommended that the crew remain aboard the Orbiter until after SRB separation, at which point more favourable abort modes become available.

In extreme circumstances, the only method of crew escape at this stage would be through the Aft Flight Deck's overhead window escape route. As the Shuttle is at this point pitched over 'heads down', this route gives the greatest chance of an escaping crew member avoiding recontacting another point on the Orbiter's structure. However, at this point there is a real danger of the crew member being engulfed by the SRB or SSME plumes.

Return-to-Launch-Site Abort (RTLS)

Should one or more engines fail early into the flight to the point where sufficient velocity will not be achieved to propel the Shuttle over the ocean to the East of the KSC, a Return-to-Launch-Site Abort (RTLS) is the recommended procedure. In this contingency, the Shuttle's main autopilot is disabled, with the attitude hold program being used to gradually pitch the vehicle upwards until it performs a complete 180° flip. With the engines now pointing in the direction of travel, the Orbiter will begin to slow itself. During this time the Shuttle should be rolled heads-up (if not done already) and pitched up in order to maintain vertical speed. Should the Shuttle drop too far before reversal of orbital speed is completed, atmospheric drag will make it impossible to reach the launch site. Once the vehicle's trajectory has been reversed to the point that the predicted landing location is just off the shoreline of the KSC, standard disconnection procedure from the ET should be followed. The OMS engines should then be briefly fired, propelling the Shuttle the final distance to the launch site. A standard landing should then be performed.

It should be noted that an RTLS abort is not possible if the payload mass is above the safe landing limits. In this case, the Shuttle should be aimed at the ocean East of KSC and a controlled bailout should be performed.

Trans-Oceanic Abort (TOA)

If the Orbiter has enough velocity to cross the ocean to the East of the KSC and reach land on the other side, but will not be able to reach orbital velocity, a Trans-Oceanic Abort is recommended. Here, the engines are shut down and the ET is detached as soon as Trans-Oceanic Velocity is reached, with a small OMS burn being completed to provide safe clearance from the ET as it reenters. As there are no viable runways for most flight paths in this direction, either a suitable area of grassland should be identified, or a controlled bailout should be performed.

Abort-Once-Around (AOA)

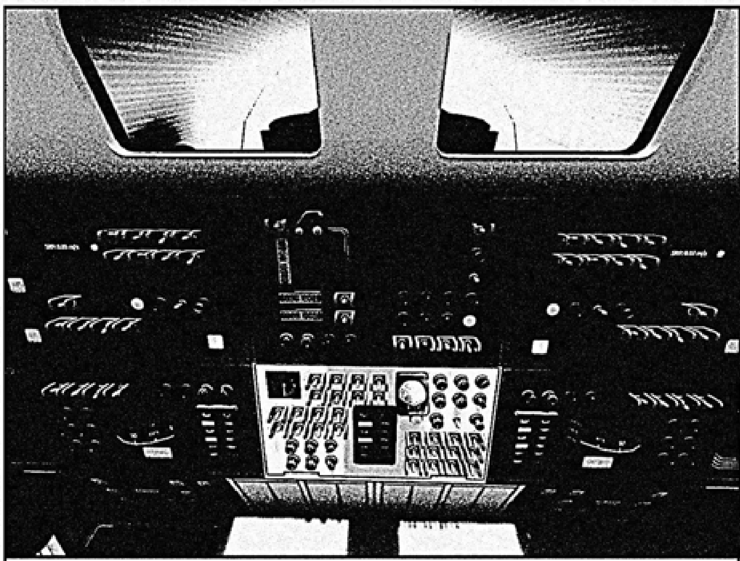
In the case that the Orbiter has sufficient energy to reach orbit but is damaged badly enough that the mission cannot be carried out, or is unable to attain a stable orbit that will not rapidly decay due to drag, the OMS engines (or RCS thrusters, if OMS engines are offline) should be used to trim the orbit such that a standard re-entry and landing at the KSC (or other appropriate landing site) can be carried out within a single orbit.

Intra-vehicular Activity (IVA) Operations

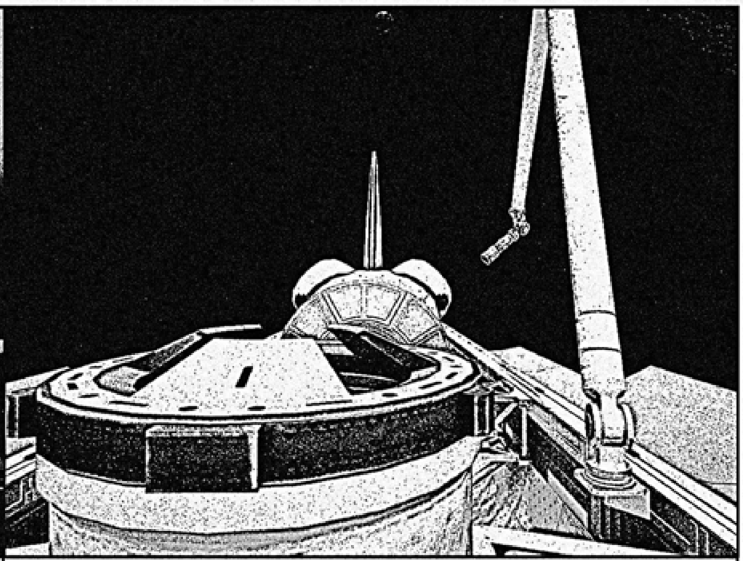
The Shuttle's internal space is divided into tow sections: the flight deck, from which the vehicle is controlled, and the mid deck, which provides living space and additional crew capacity. Four crew members sit on the flight deck, while up to three can be seated in the mid deck during launch.

Various different camera views can be accessed via double-click in the IVA. Double clicking in the space between the windows on the flight deck will provide a rear-facing view of the flight deck; clicking between the windows of the aft flight deck will place the camera at the rear of the cockpit looking out over the payload bay. All windows are individually clickable, and there are numerous other camera views that are accessible with a little exploration.

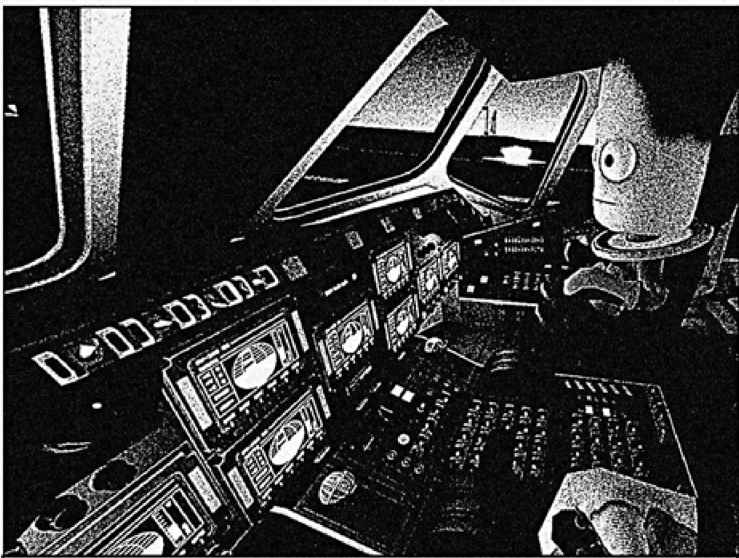
View of the Flight Deck upon landing



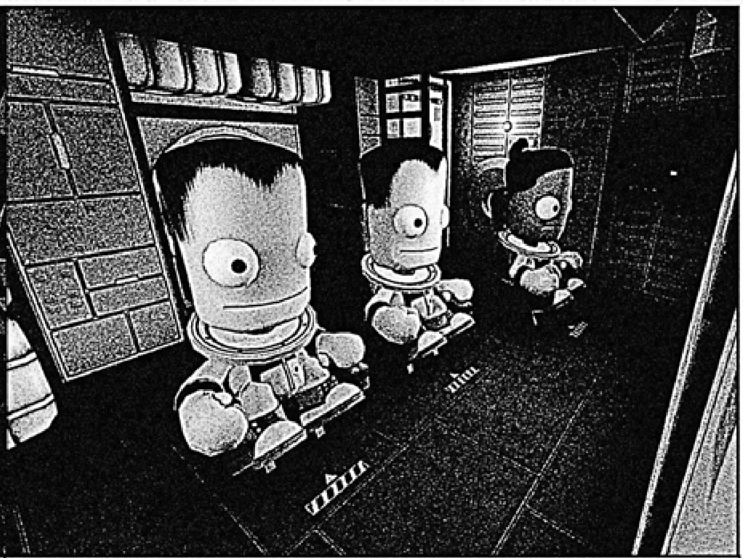
Aft Flight Deck control panel



View from the Aft Flight Deck payload bay windows



Flight deck commander’s seat



Mid deck, view facing aft

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