Launch Procedures

The Soyuz crew begin their day with a careful cleaning procedure of their bodies to avoid taking pathogens to the Space Station. Before leaving their rooms they sign the door, a tradition, which dates from the time of Yuri Gagarin.

The final countdown starts with six hours to go. The crew are taken by bus to the launch area where they put on their Sokol space suits with four hours 20 minutes to go. There is a formal military ceremony in which the crew receive official authorisation to leave for launch from the flight commission. This is the last chance to say goodbye to family, the media and the backup crew who now stay behind.

Crew on launch pad before take-off of DELTA Mission with ESA astronaut André Kuipers (below) on 19 April 2004
(Image: NASA)

Three hours and counting

Around the same time with three hours to go the propellant tanks start to be filled. The crew arrive at the launch pad 20 minutes later while checks are being carried out on the different launch stages. The Soyuz crew take a lift to the top of the Soyuz spacecraft and enter through the hatch of the utility module of the Soyuz spacecraft. They lower themselves into their seats in the landing module, which is nearly full when they take their positions: The commander in the middle (Sergei Krikalev), the flight engineer on the left (Roberto Vittori) and the second flight engineer on the right (John L. Phillips).

Soyuz launcher on the launch pad shortly before lift-off of Cervantes Mission on 18 October 2003

After being strapped in, the crew carry out checks on communications equipment before the hatch is closed with just under two hours until launch. The command/landing module is then checked and the Soyuz spacecraft is pressurised. Checks are carried out on the on-board equipment, systems, pressure and temperature before the launcher's inertial guidance systems are activated and the crew switch on their communications systems.

With one hour until launch the launcher teams are evacuated from the launch pad area. Fifteen minutes later the flight programme is loaded into the on-board computers and the service gantries rolled back. The spacesuits are checked for air tightness and the safety systems are activated with 30 minutes until launch.

With 15 minutes until launch the launch site is totally evacuated and inertial guidance systems unlocked. The automatic launch sequence becomes ready for ignition with six minutes until launch followed by activation of ground and on-board telemetry one minute later.

At 2 minutes 40 seconds until launch the avionics on the 3rd stage switch to internal power supply and the umbilical mast is disconnected. With 29 seconds remaining, the four lateral boosters together with the central core are ignited.

Launch Procedures (contd)

Soyuz TMA-1 crew in Soyuz command module just before the hatch is closed. ESA astronaut Frank De Winne (right) was participating in the Odissea Mission (30 October to 10 November 2002)

Lift-off

The Soyuz launcher and spacecraft slowly raises, starting to roll into its trajectory 20 seconds after launch. It accelerates to 4g over the first few minutes, pushing the crew back in their seats.

Two minutes after lift-off the four lateral boosters have finished burning and the acceleration drops from 4g to 1.5g. These boosters and the launch escape system are jettisoned. As soon as the core stage engines fire on full thrust, the g-forces increase again.

At about two and a half minutes, the crew get their first view of space 84 km above the Earth as the launch fairing protecting the spacecraft against atmospheric drag is jettisoned leaving an open view through the spacecraft windows. This is almost above the atmosphere.

After separation of the core stage at 288 seconds after launch, the acceleration seems to stop until the third stage engines fire at 5 minutes after lift-off. The spacecraft is now 167 kilometres high.

Seven seconds later the 2nd/3rd stage interface is jettisoned. The third stage is extinct after 520 seconds and separates at 528 seconds (8 minutes 48 seconds) after launch.

Lift off of Soyuz TMA-3 and Cervantes Mission on 18 October 2003 **(Image: NASA)**

For the first two orbits, the astronauts/ cosmonauts remain in their seats, checking all on board systems, most importantly the attitude control systems that control how the spacecraft is pointing. After checks are completed, the Soyuz is orientated in a way that the solar arrays are always directed towards the sun for power generation.

After the tasks are completed the cosmonauts can get out of their seats and take off their pressurized space suits.

Docking Procedures

Gaining altitude

Nine minutes after launch and the Soyuz is in orbit. From now on the spacecraft is floating, or more correctly, free falling around the Earth at 28,000 km per hour with an initial orbit altitude of 220 kilometres. It now takes two days to reach the International Space Station. This is because the chosen docking trajectory for the Soyuz is the most effective for fuel consumption.

The astronauts/cosmonauts cooperate with Ground Controllers who calculate the trajectory parameters, which will enable the spacecraft to conduct orbital manoeuvres to get it onto a higher orbit. These parameters are sent to the spacecraft, whereafter commands are given to fire the spacecraft's engines at certain times. Every burn of the engines increases the speed of the Soyuz vehicle and thus raises the orbit to near the trajectory of the International Space Station (380 to 400 km altitude).

ESA astronaut Roberto Vittori enters the International Space Station (27 April 2002) during the Marco Polo mission (Image: NASA)

Docking

The crew is busy with monitoring the spacecraft systems and preparing themselves in case the automatic rendezvous and docking systems fail and they have to take over manually. Mission Control on the ground can accurately track the spacecraft's trajectory, but there are still slight errors the crew has to correct with the help of the radar system and the calculations of the computer on board.

The Soyuz crew watches this flight phase on a screen inside the command capsule, dressed in their Sokol space suits. On the screen is an image generated from the periscope outside the command module. During the final approach the crew inside has to check all data and to make sure that the spacecraft is lined up properly with the docking port of the ISS. This is also monitored by Mission Control at Korolev, near Moscow.

Soyuz TMA-3 approaches the ISS during docking procedures. (20 October 2003) (Image: NASA)

Soyuz usually docks with the Station's Pirs Docking Compartment. It could also dock with the docking adapter between Zarya and Unity or at the rear end of the Zvezda module. The Progress supply vehicles almost always dock with Zvezda's aft docking port, as will Europe's ATV (Automated Transfer Vehicle) whose first launch is scheduled for 2005.

Each Soyuz spacecraft remains docked for about six months to serve as a lifeboat. If necessary, Soyuz vehicles can change their docking location to clear the occupied docking port for another approaching Soyuz or Progress supply spacecraft.

Roberto Vittori will be docking with the ISS in the Soyuz TMA-6 spacecraft and staying for 8 days before undocking and returning to Earth in the Soyuz TMA-5, which is currently stationed at the ISS.

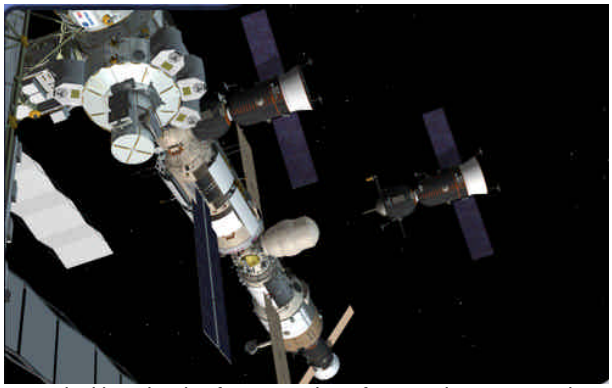
Undocking Procedures

Undocking the Soyuz TMA-5 from the International Space Station 400km above the Earth, re-entry and landing on the grassy steppes of Kazakhstan is a relatively quick procedure, taking no longer than three and a half hours.

On the last day in orbit the astronauts/ cosmonauts dress again in their special Sokol space suits, needed for launch, docking, return and landing and enter the Soyuz capsule.

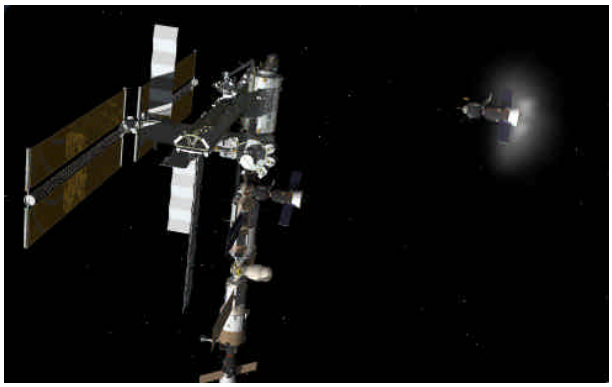
Nikolai Budarin of ISS Expedition Crew 6 in Sokol space suit preparing for undocking. (May 2003)
(Image: NASA)

The crew close the hatches and check the seals. All Soyuz board systems get activated and tested. The mission commander is responsible for pushing the undocking button. This command opens hooks and latches, which hold the Soyuz to the docking port on the ISS. Spring forces are used to push the Soyuz slowly away from the ISS.



Undocking shortly after execution of separation command
(Image: NASA)

During the first minutes the spacecraft gradually increases distance from the Station.



First short burn to lower the Soyuz spacecraft orbit
(Image: NASA)

At a 20 m distance, approximately 6 minutes after undocking, the crew fires small brake engines for 15 seconds, slowing it down.

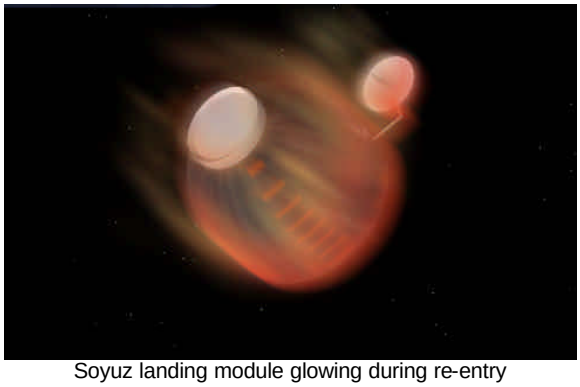
Main burn for re-entry into the denser layer of Earth's atmosphere (Image: NASA)

Re-entry Procedures

Two and a half hours after undocking, when Soyuz is at a distance of 19 kilometres from the International Space Station, the engines fire again for 4 minutes, 21 seconds. This is the deorbit burn, which gives the Soyuz an impulse against the direction of flight. As a consequence the Soyuz vehicle slows down and its orbit decreases.

Soyuz module separation (Image: NASA)

Shortly afterwards at an altitude of 200 kilometres above the ground and still an hour before landing, the Soyuz spacecraft separates into its three parts. The utility section and the instrument-assembly module burn upon re-entry in the denser layers of Earth's atmosphere.



Soyuz landing module glowing during re-entry
(Image: NASA)

The same would happen to the landing module, however it is protected by a heat shield and further assumes a shallower aerodynamic flight profile on re-entry.

After separation, the landing module is given the command to rotate. This manoeuvre puts the strongest parts of the heat shield towards the re-entry direction, so that it can absorb most of the friction heat. Re-entry occurs at an altitude of approximately 120 kilometres where it enters the upper layers of the atmosphere. This is half an hour before landing. Soyuz is at this point over South America.

It will follow a trajectory across the Atlantic Ocean, Africa and the Middle East and eventually land in Central Asia. The cosmonauts can see a red glowing outside the window during this period of descent caused by the friction from the airflow, which heats the outer spacecraft shell.

The speed is reduced dramatically and the crew is pushed back into their seats by a force of 4 to 5 g. This is equivalent to four to five times their own body weight.

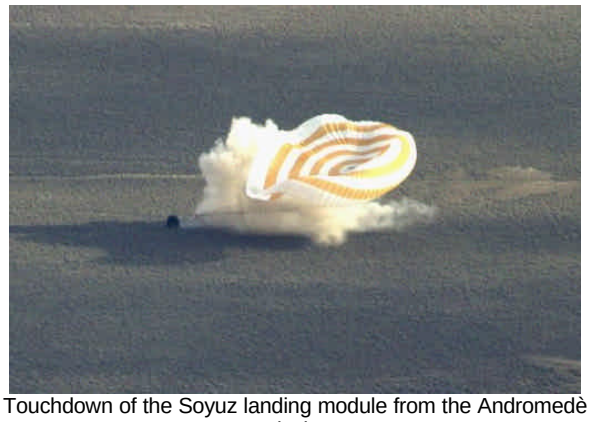
Landing Procedures

The Andromedè Mission landing module after re-entry and before landing (31 October 2001)

Fifteen minutes prior to landing at an altitude of 12 kilometres the parachutes begin to deploy while Soyuz is still at a speed of 900 km/h. First, two pilot parachutes open followed by a 24 square metre drogue chute, at an altitude of 10,5 kilometres. This slows the Soyuz to 360 kilometres per hour.

At this point the 1000 metre square main parachute opens, slowing the Soyuz to 25 km/h (7 m/s). Soyuz travels at an angle of 30 degrees for cooling purposes due to a special parachute harness. The capsule then changes to a vertical descent. As a backup, there is an emergency parachute half the size of the main parachute. This would be released automatically at a certain height.

At 4 km above the ground the heat shield is jettisoned, further reducing descent speed until one second before touch down. This is at a distance of 80cm above the ground when six soft landing engines fire to reduce the speed to 7 km/h (2 m/s). The Soyuz TMA spacecraft possess two engines, which reduce landing speed and forces by 15 to 30 per cent.



Touchdown of the Soyuz landing module from the Andromedè Mission

Further cushioning the impact of landing are the crew seats with their custom-fitted liners. The liners are individually moulded to each astronaut's/cosmonaut's body.

Artists impression of Soyuz landing module after touchdown (Image: NASA)

Immediately after ground contact the parachute cords are cut to avoid any wind disturbance. A communication antenna is hereafter deployed so that the recovery team will find the crew as soon as possible.

Soyuz TM-33 after landing with ESA astronaut Roberto Vittori. (5 May 2002) (Image: NASA)

Post-Landing Procedures

Ground control in Moscow and Baikonur follow the touch down of Soyuz. Recovery equipment, helicopters, and tents, are prepared for the landing, with a recovery and support team consisting of physicians, psychologists, officials and military personnel from Baikonur.

After landing, the crew deploy at least one communication antenna, so that the rescue teams can pinpoint their precise location on the vast expanse of the Kazakh Steppes.

Soyuz TM-33 landing site with ESA astronaut Roberto Vittori on board. The communication antenna, extraction stand and chairs are visible (Image: NASA)

The landing accuracy is within a range of 30 kilometres. Soyuz spacecraft land nominally on land, in two areas in northern Kazakhstan, one near the town of Arkalyk, the other near the town of Dzhezkazgan. Nevertheless a Russian manned mission could also touch down anywhere in the world including on water, as happened once before.

Recovery teams in helicopters approach the landing site soon after landing. Immediately after arrival the hatch is opened and an extraction stand is assembled to assist the Soyuz crewmembers to exit the spacecraft. Other helpers are responsible in cordoning off the area and gathering the spacecraft's landing parachutes.

In case of a delay reaching the landing site the astronauts/cosmonauts are trained to help themselves having had extensive survival training in the mountains and Caspian Sea.

After leaving the capsule each cosmonaut is eased into a chair where they can relax and answer any first questions by the recovery team. In the meantime, a medical tent is prepared for the first medical checks, still on site.

Soyuz TM-33 commander Yuri Gidzenko is helped into a chair after landing (Image: NASA)

The cosmonauts are brought by helicopter to an intermediate stop at Astana, the capital of Kazakhstan. At the same time technicians prepare the Soyuz spacecraft for removal from the landing site.

The medical tent, surrounded by a helicopter and landing parachute (Image: NASA)

From Astana, the crews are further transported by plane to Star City near Moscow where they stay in quarantine for two weeks for further medical checks, readaptation to life on the ground and mission evaluations. The families are also waiting there.