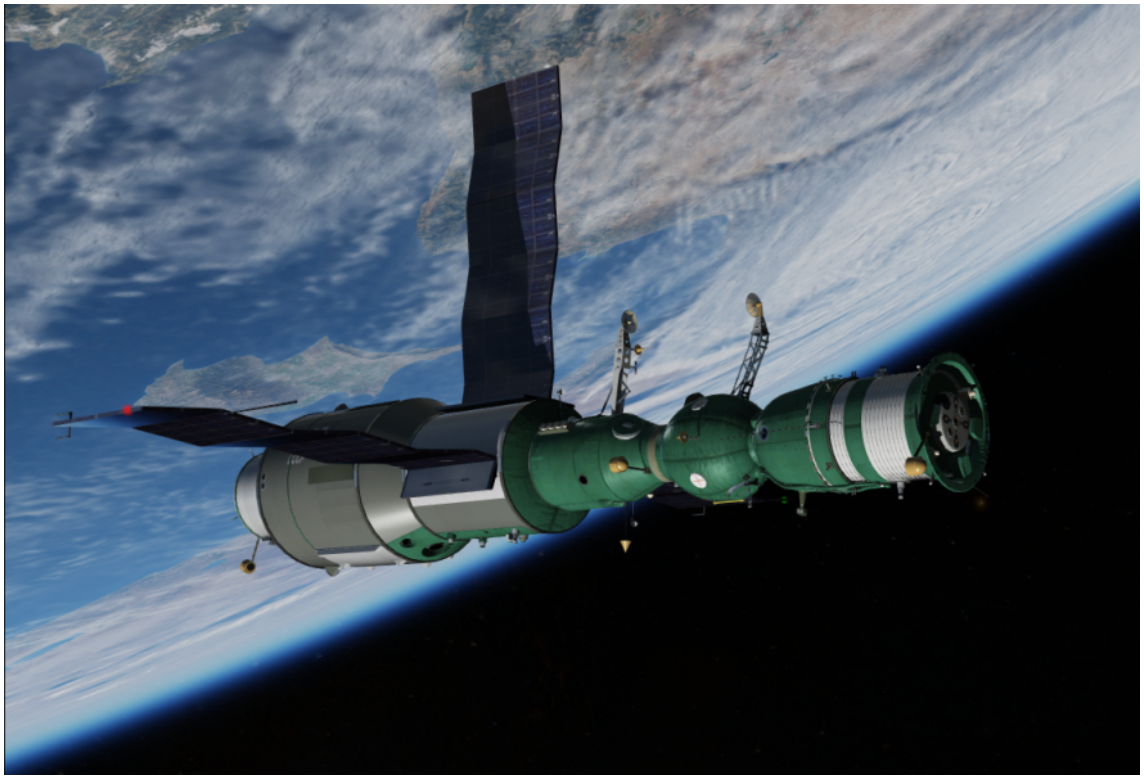
Soyuz 7K-T: Flight Guide



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1 Introduction

This document is intended as a summary of the necessary procedures to complete a full Soyuz 7K-T flight, to and from a space station. It focuses on one particular mission profile, and provides some context on the systems described in the accompanying manual.

The mission profile is that of a typical flight to a Salyut space station, and can be used with the included scenarios. The Soyuz spacecraft is launched into orbit by the Soyuz-U rocket, at such a time that it will be trailing Salyut in a lower orbit. The rendezvous will allow some time (maximum of two days) in a phasing orbit to catch up to the station, until the moment of the final rendezvous, when the transfer orbit is established. Approach and docking are performed with the Igla automatic system.

Only one external tool is used in the guide: TransX to set up the rendezvous trajectories. SyncOrbitMFD can also be used in a manual mode, but TransX is recommended for more accurate planning of the orbit corrective manoeuvres, which will also allow use of the automatic burn programs of the Soyuz.

The user should be familiarised with the internal instruments and the ship systems by reading the accompanying manual. Remember to perform any manual orientation manoeuvres in the orbital portions of flight using the DO system, to conserve DPO fuel for the approach.

2 Pre-launch

When the launch scenario starts, the Soyuz is minutes away from lift-off. Launch is entirely automatic, but some items need attention:

- Turn on the ELS for in-flight signaling - on the far right of the main panel, under the digital BTSI unit, press in the ELS button;
- Activate KSU control - on the main panel, critical commands section, press in the corresponding button for the KSU to be used, left or right;
- Set up the location on the INK globe - using the inner knob to rotate the globe around the polar axis, and the outer knob to rotate the globe along the orbital axis. Begin by locating the Tyuratam launch site (Radio Station 1), then rotate along the orbital track until just west of Lake Baikal. This should be the rough position at orbit insertion which can be fine-tuned later.

3 Launch and Orbit Insertion

3.1 Launch

During launch, which is fully automatic, the role of the pilot is that of monitoring the spacecraft systems to ensure all is nominal (for the moment, no failures are simulated).

3.2 Orbit Circularising

Once the orbit insertion is complete, the spacecraft is separated from the rocket and the In-Orbit portion of the flight begins. Antenna and sensor deployment is automatic, and will be complete one minute after separation.

On insertion, the orbit will be elliptical, so the periapsis will need to be raised to circularise the orbit and insert the Soyuz into the phasing orbit. To that end, the Orbital Orientation should be established upon reaching orbit:

- KSU: Select column K, activate "BDUS" (K-3)
- KSU: Select column P, check that Orientation Stabilisation is set to "X BKWD" (P-17);
- KSU: Select column K, activate "Orbital Orientation Mode" (K-9).

Upon reaching apoapsis, the SKDU should be used to circularise the orbit into the Phasing Orbit. This can be done with the standard Orbiter commands and OrbitMFD, or the manoeuvre can be planned by determining the needed Delta-V. From the main panel, critical commands, the SKDU ON and SKDU OFF buttons can also be used to control the burn.

Upon reaching the new orbit, the INK instrument should now be updated with the new parameters:

- From OrbitMFD, get the orbital period (T), and divide by 60 to obtain the orbital period in minutes;
- Set the INK mode selector knob to the OFF position;
- Enter the new orbital period into the INK period counter;
- Using the adjustment controls, adjust the position of the spacecraft over the surface as accurately as possible. Use outside references if possible;
- Re-activate the instrument.

After this correction burn, the Orbital Orientation mode can be left on, or disengaged with the "Modes OFF" KSU command (K-1).

During the next orbit, an initial checkup of the SSVP is performed, and the docking probe is extended:

- KSU: Select Column S, activate "SSVP Power" (S-1);
- KSU: Select Column ZH, activate "Rod Extension" (ZH-1);
- Extension takes 6 minutes, confirm extension by the turning off of the indicator light;
- Latch extension is automatic following rod extension and takes 2 minutes, confirm extension by the turning off of the indicator light;
- KSU: Upon completion of the rod and latch extension, the indicator "Docking Mechanism Ready" (ZH-25) will light;

- KSU: Select Column S, deactivate "SSVP Power" (S-2).

The SSVP is now prepared for the approach, and powered down during the coasting phase to conserve battery power.

When using TransX to set up the rendezvous, this is a good time to determine the burn parameters:

- Open TransX;
- If necessary, use the VAR keys to select "Select Target";
- Use the ADJ keys to select "Ships"target mode;
- Use the ++ key and enter the target ship's name;
- Use the VAR keys to select "Orbits to Icept" mode;
- Use the ++ key to set 0.5;
- Press the VW key to switch to the "Manoeuvre" view;
- Use the VAR keys to select "Manoeuvre mode";
- Use the ++ key to set On;
- With the VAR keys, navigate to "Prograde vel.";
- Use ++ or – to change the Delta-V, use the ADJ keys to adjust the rate of change between Coarse and Hyper, as needed;
- Start with a Delta-V of around 30 m/s, then use the VAR keys to navigate to "Man. date", this will be the date of the rendezvous burn;

- Adjust the date with ++ and –, and the rate with the ADJ keys, until the closest approach reaches a minimum;
- Iterate tuning of "Prograde vel." and "Man. date" until the closest approach is 1 km or under;
- Use the VW key to switch to the "Target" view;
- You now have the remaining time until the burn. Use this and the final date on the previous step to plan accordingly.

During the coasting phase, the Soyuz can be allowed to drift freely, with no requirement to be oriented at the sun. However, the attitude can be gyro-stabilised by placing the Soyuz in a constant yaw of 2.5 degrees/second:

- Confirm DO is active;
- KSU: Select column K, activate "BDUS" (K-3);
- KSU: Select column K, activate "Impulse-RO" mode (K-7);
- Yaw to a rate of 2.5 deg/s;
- KSU: Select column K, activate "Modes Off" (K-1).

4 Rendezvous, Approach and Docking

4.1 Rendezvous Initiation

At least 30 minutes before the planned burn time to begin the rendezvous, repeat the procedure from the Orbit Insertion section to engage the Orbital Orientation mode.

While orientation is established, the Integrating Accelerometer should be powered on:

- KSU: Select column K, activate "Integrating Accelerometer" (K-19);
- Current value of accumulated speed change can presently only be monitored in HUD mode.

This accelerometer will be used to monitor the Delta-V, determined by TransX, during the burn. At a later date, the automatic correction programs making use of this accelerometer will be added.

At the planned burn time, turn on the SKDU and monitor the Delta-V, until the intended value is reached. The Soyuz is now on its way to Salyut.

4.2 Approach

In half an orbit, the closest approach to Salyut will happen. After the previous SKDU burn, Orbital Orientation should be established. At this point, using Orbiter's default tools, tune into Salyut's transponder frequency to have far range information. Some SyncOrbitMFD modes will also always tell the distance.

- As the relative distance nears 30 km, turn off the Orbital Orientation hold and power the SSVP;
- KSU: Select column K, activate "Modes Off" (K-1);
- KSU: Select column K, activate "BDUS" (K-3);
- KSU: Select column S, activate "SSVP Power" (S-1);
- Once the distance is under 30 km, activate Igla;
- KSU: Select column ZH, activate "Approach" (ZH-7).

Igla will begin orientation towards Salyut and begin providing range and range-rate information. As the two spacecraft approach, Salyut will also orient itself towards Soyuz, and Soyuz will perform several high-rate turns with DPO and use the SKDU to slow its approach and reduce motion of the line of sight. Range and range-rate can be monitored on the HUD or on the main panel.

Under a range of 1 km, the control law is purely line of sight, Soyuz locked on Salyut and vice-versa. No input shall be required, but in case of deviation or pilot intention, from a range of 200 m the approach can be switched to manual:

- KSU: Select column ZH, activate "Manual Approach" (ZH-5).

This will allow a manually controlled, visual final approach and docking, while keeping Igla's range and range-rate information as before.

Upon contact, the Soyuz will be soft-docked to Salyut, and Igla will automatically turn off to prevent unwanted thruster firings. Note that docking

will only be possible if the SSVP was correctly configured. The docking sequence can then proceed:

- KSU: Select column ZH, confirm "Contact" indicator (ZH-26);
- KSU: Select column S, activate "Rod Retraction" (S-5);
- Monitor the hard-dock sequence. Partial Rod retraction is followed automatically by Hooks closing (3 minutes, S-7 indicator) and Latches closing (2 minutes, S-3 indicator), concluding with final Rod retraction;
- KSU: Select column ZH, confirm hard-dock with "Mechanical Capture" (ZH-27);
- KSU: Select column S, deactivate "SSVP Power" (S-2).

Welcome to Salyut! Don’t forget to retune the INK with the new orbital parameters, using the previous method.

5 Undocking and Descent

5.1 Undocking

Undocking from the station is done by automatic sequencing. Starting from a hard-dock state:

- KSU: Select column S, activate "SSVP Power" (S-1);
- KSU: Select column S, activate "Undocking" (S-9);
- KSU: Select column ZH, monitor "Hooks Opening" (ZH-19);
- Hooks opening duration is 3 minutes, after which the Soyuz is mechanically unlinked from the station, and separation is introduced by spring pushers;
- KSU: Select column S, deactivate "SSVP Power" (S-2).

Use DPO translation as needed to increase separation from the station.

5.2 Descent

Delta-V for the de-orbit burn, where H is the circular orbital altitude, should be as follows:

- For H < 300 km, Delta-V = 89.6 m/s;
- For 300 km < H < 330 km, Delta-V = 102.4 m/s;
- For H > 330 km, Delta-V = 115.2 m/s.

The landing angle for a ballistic re-entry from a circular Salyut orbit of H = 350 km is approximately 128 degrees.

5.2.1 Automatic Descent

5.2.2 Descent with RO

5.2.3 Manual Descent

At least 30 minutes before the planned de-orbit time, engage the retrograde Orbital Orientation:

- KSU: Select column K, activate "BDUS" (K-3)
- KSU: Select column P, check that Orientation Stabilisation is set to "X FWD" (P-15);
- KSU: Select column K, activate "Orbital Orientation Mode" (K-9);
- KSU: Select column K, activate "Integrating Accelerometer" (K-19).

To know when to start the de-orbit burn, use the INK in Landing Angle mode:

- Enter the desired angle in the Landing Angle counter;
- Switch the INK mode to MP - Landing Angle;
- Begin the burn when the landing site is centred.

At the moment of the de-orbit burn:

- KSU: Select column K, activate "Modes Off" (K-1);
- KSU: Select column K, activate "BDUS" (K-3);
- KSU: Select column K, activate "Integrating Accelerometer" (K-19);

- KSU: Select column I, activate "Inertial Orientation" (I-15);
- Turn on the SKDU, monitor the Accelerometer value;
- At the previously established Delta-V value, turn off the SKDU.

The inertial attitude hold will set the right attitude for the module separation event. This should occur at an altitude of 140 km:

- At H = 140 km, attitude should be approximately 90 degrees relative to the horizon, with the BO towards the Earth, and the Vzor towards the velocity vector;
- Separate both modules: J key twice;
- KSU: Select column V, monitor "ASP" activation (V-1). If off, manually arm it at this point;
- KSU: Select column V, monitor "Separation" indicator (V-25).

At separation, the Descent Control System (SUS) will engage automatically and control the descent. From this moment on, guidance is fully automatic.

5.3 Re-entry

- Motion of the SA should be in pitch only, and pitch is allowed to change at up to +-2 deg/s with limiting by thruster firings. Simulation speed is automatically set to 1x on corrections;
- SA will oscillate in pitch until settling in the balanced position around the trim angle of attack, before entry interface (EI) around H = 80 km. This should be around 21 degrees in Angle of Attack;

- KSU: Select column V, monitor "Atmosphere" indicator (V-26) for EI indication. HUD view also shows accumulated deceleration, with 25.6 m/s indicating EI.

At this point, atmospheric re-entry begins in either guided or ballistic mode. Refer to the manual for the description of the guidance on each. If re-entry is ballistic, the ELS will indicate it.

5.4 Landing

Once the accumulated deceleration reaches 7200 m/s, the re-entry phase is over:

- At H = 10.5 km, the main parachute cavity cover is jettisoned and the drogue chute is deployed, slowing the SA from 230 m/s to around 70 m/s;
- At this point, ballistic mode is either engaged or continues on;
- At H = 8.5 km, the drogue chute is released and the main chute is deployed. ELS main parachute indicator is lit;
- At H = 5.5 km, several events occur: the heatshield is separated and drops below the capsule. The ballistic mode is disengaged and rotation around the longitudinal axis stops. The remaining thruster propellant is vented completely. ELS 5.5 km indicator is lit;
- The ELS Landing indicator lights at H = 15 m. Descent speed has reduced to around 6 m/s;
- At H = 2 m, the soft landing thrusters fire. Welcome home, cosmonaut!