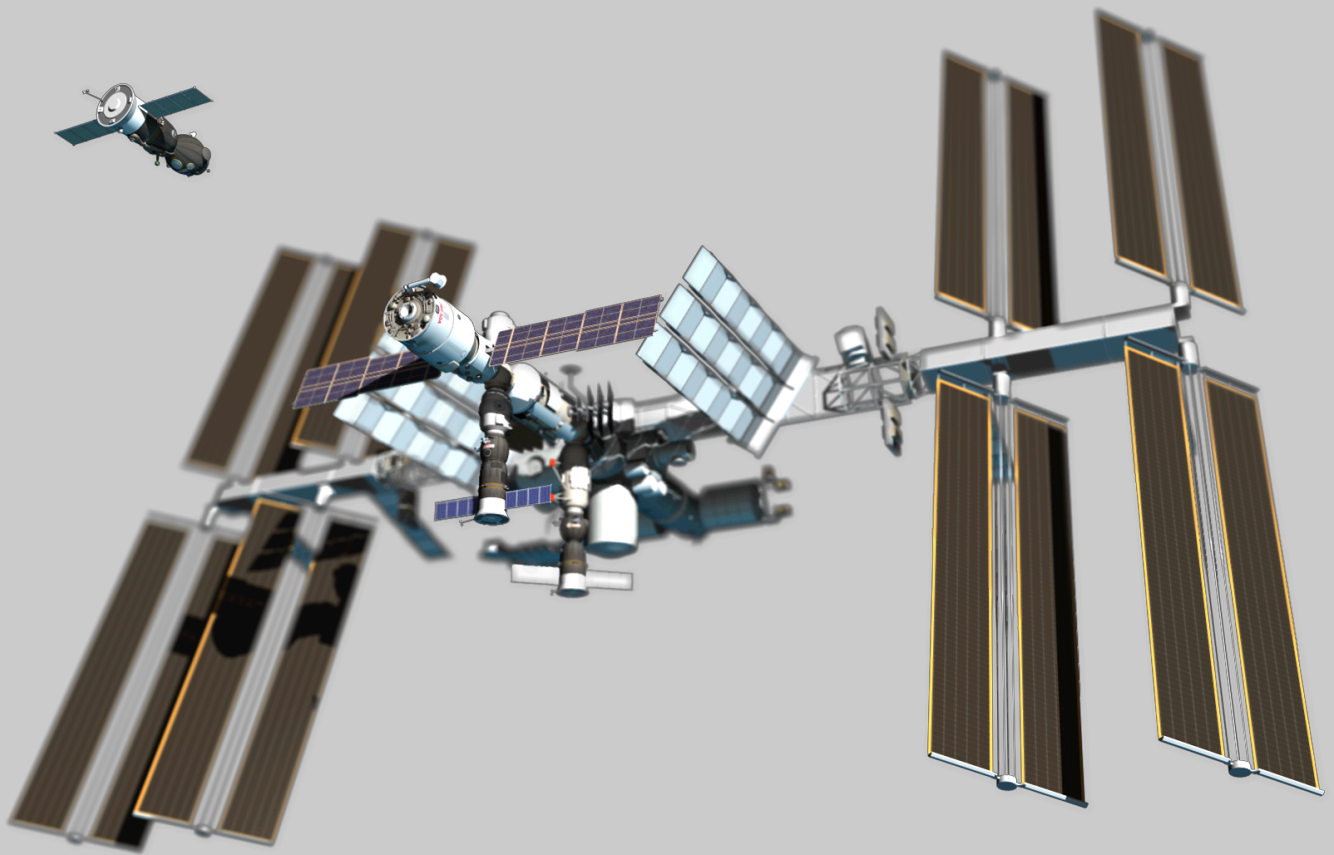


SOYUZSIM

USER GUIDE



December 2019

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Welcome

[SoyuzSim](#) is for whom wants to learn how to manually maneuver the legendary Soyuz spacecraft during on-orbit operations around the [International Space Station](#) (ISS).

Thanks to a very realistic simulation environment, [SoyuzSim](#) brings on your [Android device](#) the basic Soyuz's manual piloting capabilities that could nevertheless help a cosmonaut in maneuvering the spacecraft in outer space with an accuracy of centimeters.

This User Guide provides the background and specific information you may need. The way information is introduced takes into account non-expert audience.

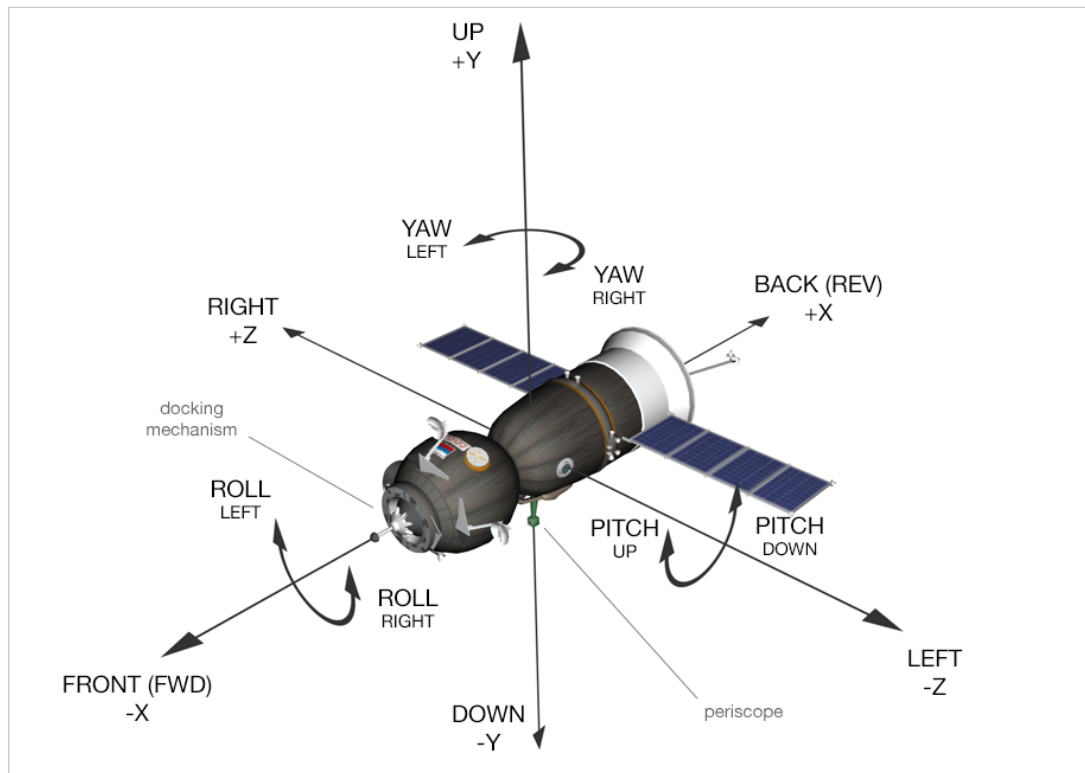
Have fun!

European astronauts
and Russian cosmonauts who tried it,
complimented [SoyuzSim](#) for its realism.

[SoyuzSim](#) is a major evolution of
SoyuzSimulator (Android app, 2012),
and *soyuzSim* (iOS app, 2015).

Background information

Soyuz spacecraft



Length: 7.48 m Max diameter: 2.52 m

Span: 10.70 m

Mass: 7,150 kg

A Soyuz spacecraft consists of three parts. From front to back:

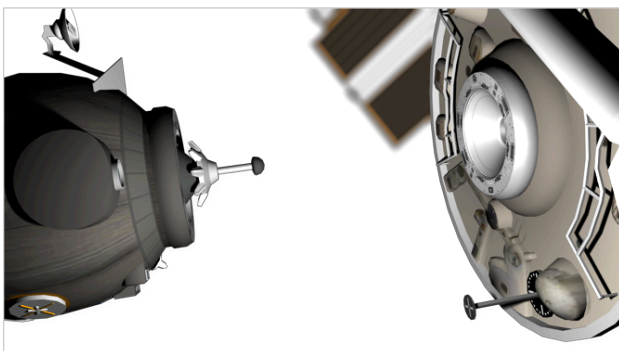
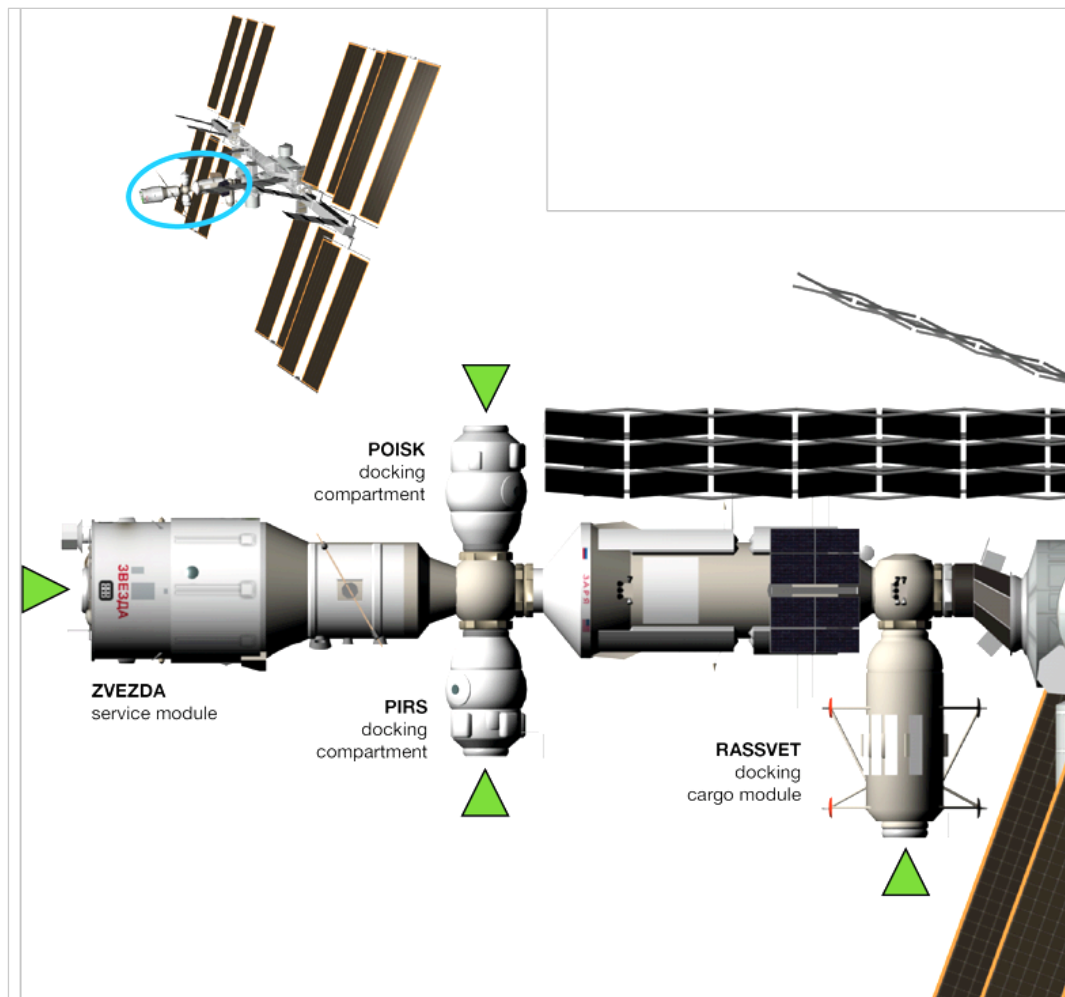
- **Orbital module** – The forepart of the spacecraft contains docking avionics, communications gear, a toilet, and all the equipment that will not be needed for re-entry.
- **Descent module** – Also known as “re-entry capsule”, it is used for launch and the journey back to Earth.
- **Service module** – It contains systems for temperature control, electric power supply, long-range radio communications, radio telemetry, instruments for orientation and control, the main engine, and a liquid-fuelled propulsion system for maneuvering in orbit and initiating the descent back to Earth

A **periscope** on the “belly” provides an external frontal view to the crew from 1.8 m “under” the center of mass of the spacecraft.

The Soyuz can translate and rotate around its center of mass.

Russian segment of ISS and docking ports

The Russian segment at the back of the ISS consists of five modules. There are four docking ports, designed for crew and cargo transfer, where the Soyuz and the Progress cargo vehicles can dock. Between 2008 and 2014, five Automated Transfer Vehicles, all developed by the European Space Agency (ESA), eventually docked to the port located on the Zvezda module.



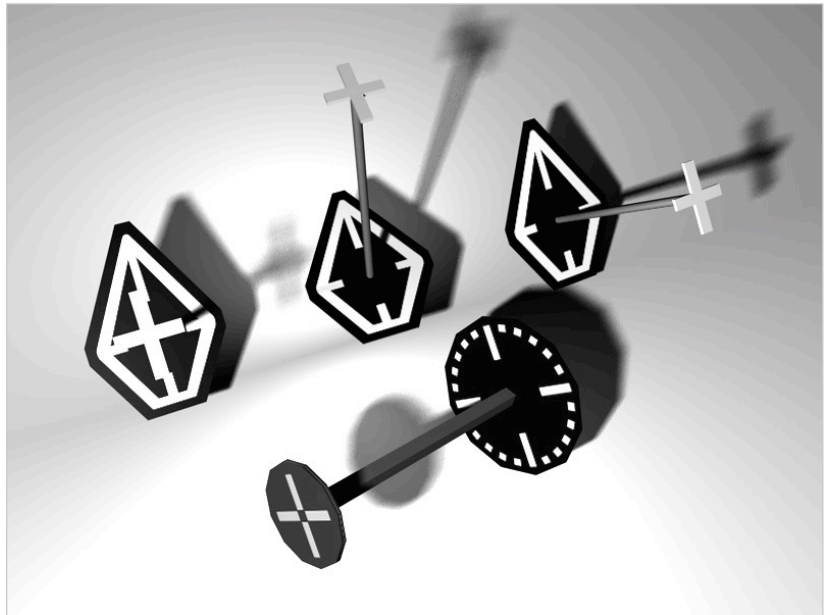
The Russian [docking mechanism](#) is based on the classical "drogue-and-cone" design.

A [docking target](#) helps in aligning the Soyuz to a docking port during the final approach. Each docking port has a docking target installed at a distance compatible with the Soyuz's periscope point of view (the crew's viewpoint).

A **docking target** consists of:

- A round or 5-sided base, not bigger than an A3 page, with white signs.
- A stick mounted on the base.
- A white cross, mounted on the top of the stick.

The position of the whole **docking target** and the position of its white cross with respect to its base, give an idea of what corrective translational/rotational movements are required to better align the Soyuz to the designated ISS docking port.

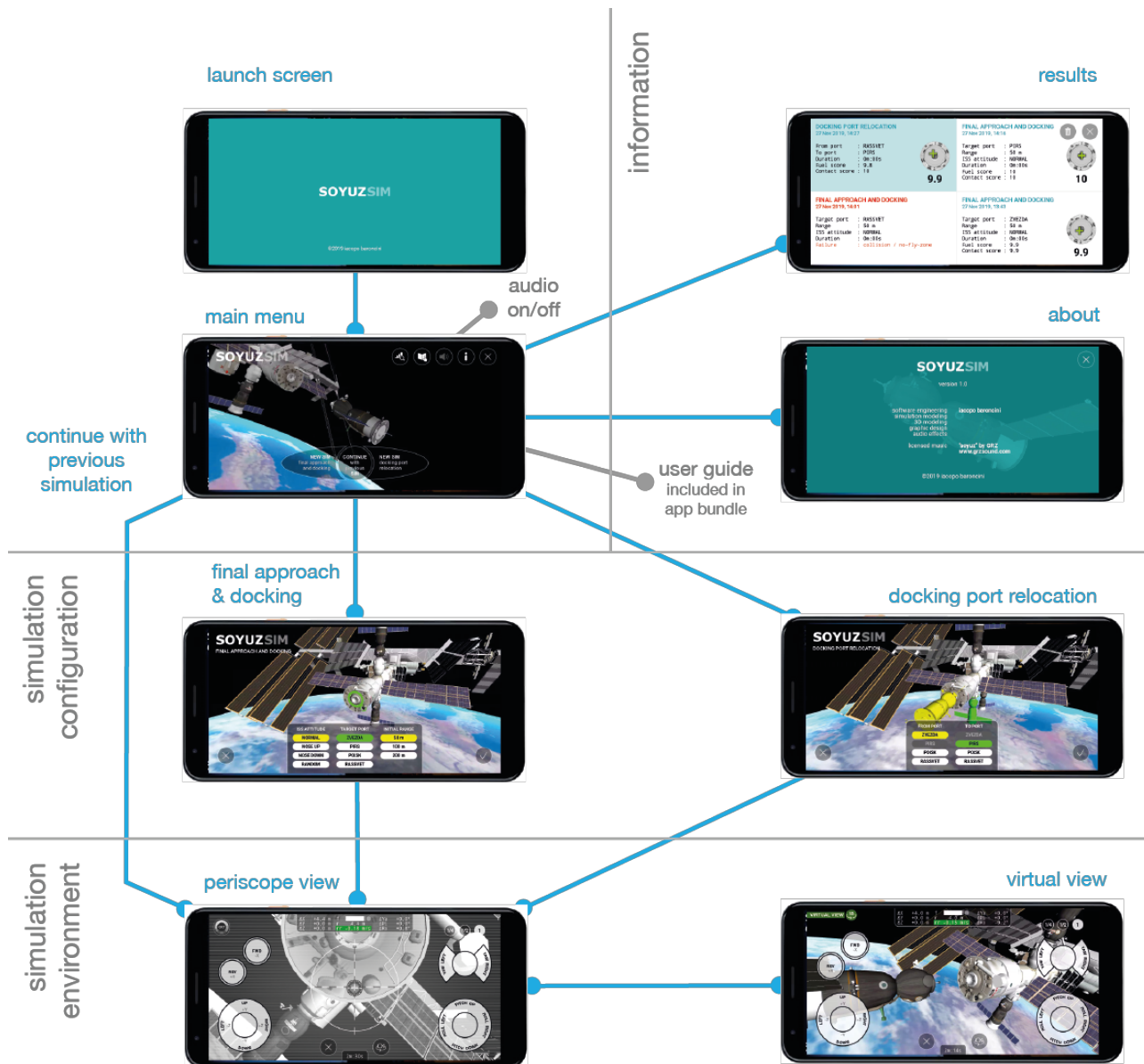


From the periscope point of view, the Soyuz is well aligned with the designated ISS docking port when:

- The whole docking target is very close to the center of the grid.
- The docking port's cone is very close to the up direction, within a certain margin.
- The white cross of the docking target is seen within its base.
- The angle of incidence is within a certain margin.



App structure



When **SoyuzSim** runs in foreground it makes heavy use of memory and GPU resources that are eventually released when the app is suspended or closed.

Simulation environment

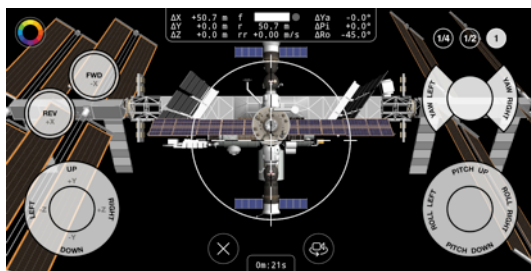
Views

The **periscope view** provides an external frontal view, from 1.8 m under the center of mass of the spacecraft. With the **shading button** (top-left side) you can change the shading of this view to the one you like the most. Three options are available: color shading, B&W shading, and B&W + CRT shading.

The **virtual view** provides an external overview. You can move the virtual camera by swiping your finger on the screen.

You can switch between the two views with the **camera switch button** (bottom side)

Commanding capabilities, when enabled, are visible and functional in both views.



Periscope view (color shading)



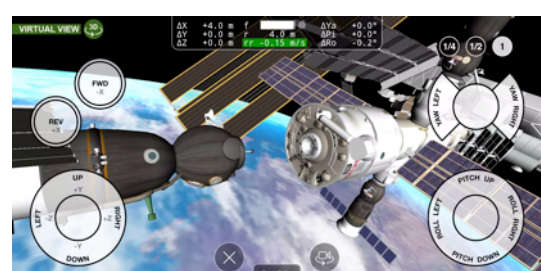
Periscope view (B&W shading)



Periscope view (B&W + CRT shading)



Virtual view



Virtual view (short range)

Command controllers


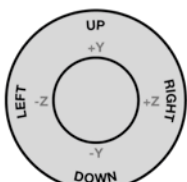
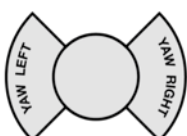


Two command controllers allow you to fine adjust the velocity vector and the attitude of the Soyuz during on-orbit operations around the ISS.

The **translation controller** on the left side governs the changes to the velocity vector of the Soyuz in six directions: forward (-X) or backward (+X), left (-Z) or right (+Z), up (+Y) or down (-Y)

The **attitude controller** on the right side governs the changes of the attitude of the Soyuz: pitch, yaw, and roll.

Since the periscope objective is located 1.8 m “under” the center of mass, you will notice that rotations are not centered with the periscope view.

The controllers can be used simultaneously.

	Command(s)	Function	Notes	Type
Translation controller		They provide constant acceleration along X-axis (forward, reverse).		Buttons
		It provides variable accelerations along Z-axis (side) and Y-axis (vertical).		Joysticks
Attitude controller		It sets a variable target angular velocity around Y-axis (yaw).	Angular velocities around axis increase or decrease until the target angular velocities are reached.	
		It sets variable target angular velocities around Z-axis (pitch) and X-axis (roll).		
			They set maximum angular velocities to 0.75, 1.5, or 3.0 deg/sec.	Selection depends of the need of how to change the attitude, in terms of speed and accuracy.

Joystick controls

- *Activation* – Put your finger in the central circle. The image of a blue handler will be displayed.
- *Commanding* – Drag your finger in the desired direction. Its position is translated in values, whose intensity is proportional to the distance of the finger from the central circle.
- *Release* – Remove the finger from the screen. The command is automatically released when the finger gets too far from its center, as it would happen with a real joystick.

About “angles hold” feature

When the attitude controller’s joysticks are released, the Soyuz continues to rotate due to inertia. Engines fire in order to automatically rotate the Soyuz “back” to the attitude angles at the time joysticks have been released.

About fuel consumption

Any translation (changes to the velocity vector) always requires “forces”.

- Engines are used.

Any rotation (changes in attitude) requires fuel only when the angular velocity changes, including during the angles “hold” corrections.

- Engines are used until the actual angular velocities are different from the target ones.
- Engines are not used in case of constant angular velocities (“free rotation”).
- Changing angular velocities as less as possible, saves fuel.

Data display



Label/object	Function	Notes
$\Delta X, \Delta Y, \Delta Z$	Delta contact distance <ul style="list-style-type: none"> Projections on the X/Y/Z-axis of the vector connecting the docking element at the front of the Soyuz in its current position and as if it is perfectly docked to the designated ISS docking port. Measurement unit: meter (m). 	At short range, you have to translate the Soyuz in order to bring these values as closer to 0 (zero) as possible.
f	Fuel Fuel gauge that indicates the level of fuel available for the simulation.	Engines are used during translations and until the actual angular velocities are different from the target ones.
●	Engines usage indicator Led-like indicator that lights up when at least one engine is firing.	Engines are not used in case of constant angular velocities (no rotation or “free rotation”). Changing angular velocities as less as possible, it saves fuel.
r	Range <ul style="list-style-type: none"> The distance between the docking element at the front of the Soyuz and the designated ISS docking port. Measurement unit: meter (m). Positive value. 	
rr	Range rate <ul style="list-style-type: none"> The rate at which the range is changing with respect to time. Measurement unit: meter per second (m/s). A backlight shows if it is nominal (green) or not (red). <ul style="list-style-type: none"> Nominal if within [-0.20, -0.10] m/s. Active when range is less than 10 m. 	Negative when the Soyuz is getting closer to the designated ISS docking port (range decreases). At contact, range rate shall fall in the nominal interval, so the docking system can properly work.
$\Delta Ya, \Delta Pi, \Delta Ro$	Delta attitude <ul style="list-style-type: none"> Differences between the current attitude of the Soyuz and the correct attitude required for a perfect docking to the designated ISS port. Measurement unit: degree. 	At short range, you have to rotate the Soyuz in order to bring these values close to 0 (zero).

Simulation goal and initial conditions

Simulation goal

Regardless the initial simulation conditions you choose, the goal is to successfully dock the Soyuz to a designated ISS docking port.

At contact, a successful docking requires:

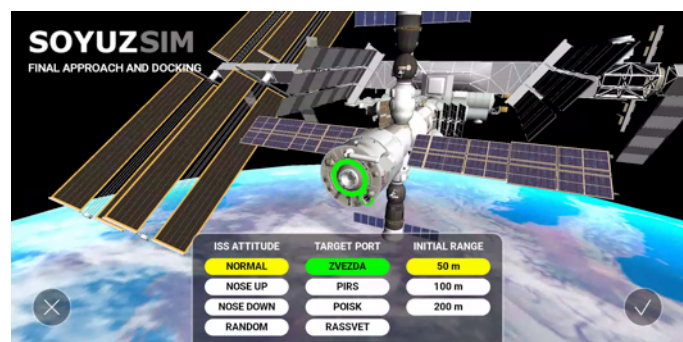
- The Soyuz's **docking probe** to be inside the receiving cone of the designated ISS docking port.
- The **range rate** to be $[-0.20, -0.10]$ m/s (the range between the Soyuz and the designated ISS docking port at contact shall decrease no more than 20 and no less than 10 centimeters per second).
- The Soyuz is well aligned with the designated ISS docking port:
 - **Angle of incidence** less than 10 deg.
 - **Delta roll angle** less than 10 deg.

Simulation scenarios and initial conditions

There are two types of **simulation scenarios** you can choose from.

Final approach and docking

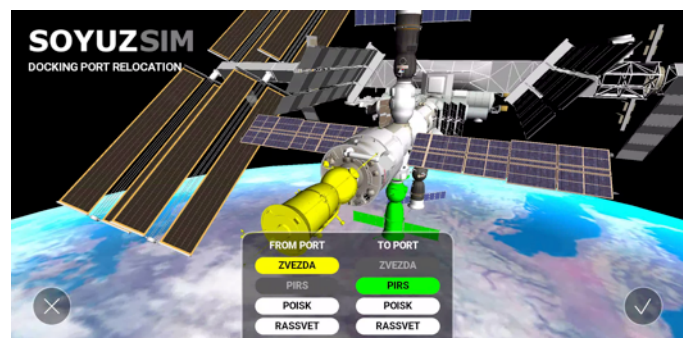
Six hours after launch from Baikonur, Kazakhstan, the Soyuz arrives in the proximity of the ISS, and it is ready to go for docking. Initial conditions in this simulation scenario differ by ISS attitude, designated docking port, and initial range.



Docking port relocation

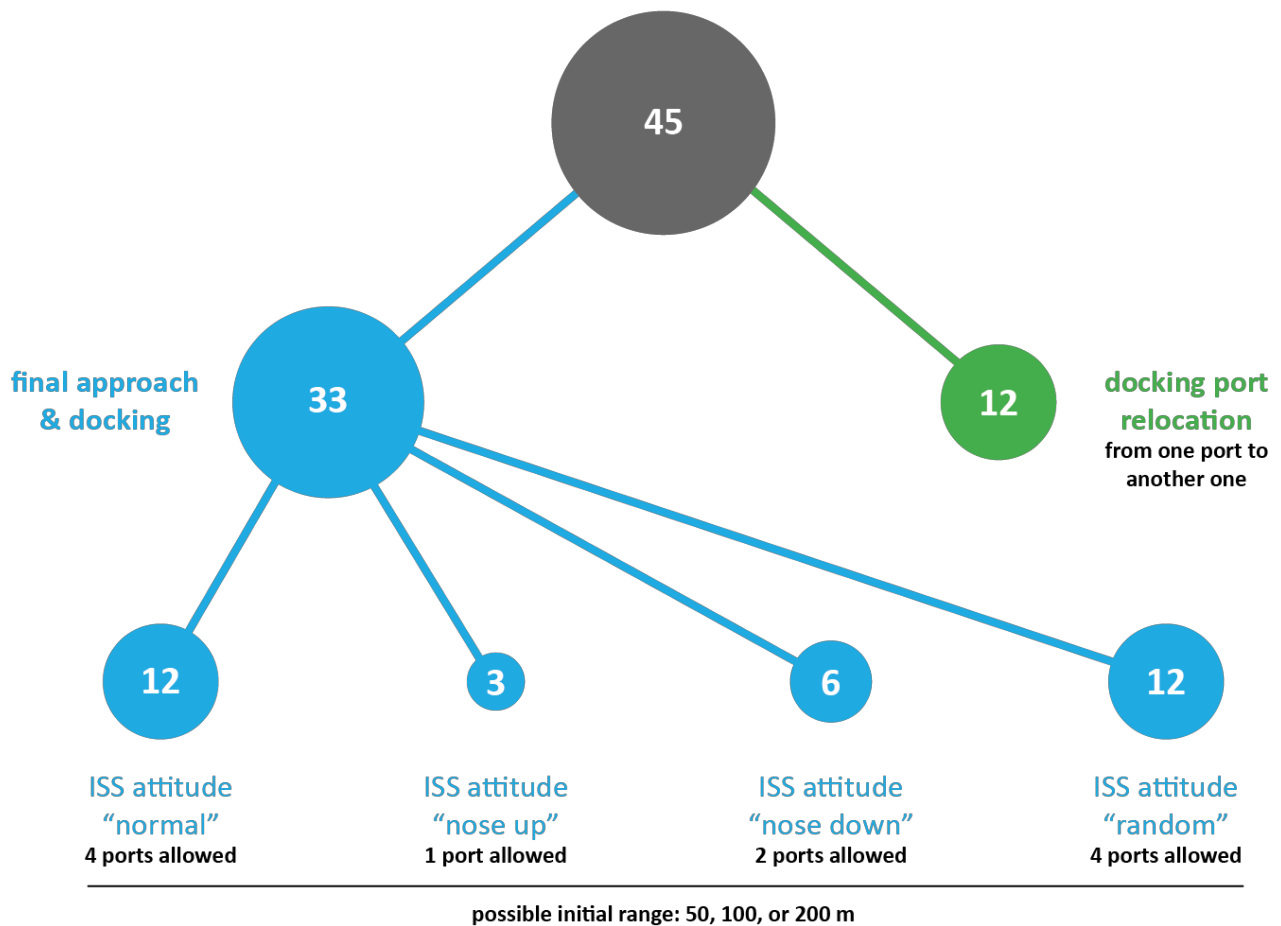
This is necessary when an incoming visiting vehicle needs to dock to the specific docking port where the Soyuz is currently docked.

The Soyuz undocks from an ISS docking port and must be docked to another designated one. Initial conditions in this simulation scenario differ by departure and arrival ports.







While configuring a new simulation scenario, a 3D overview provides a representation of you current choices.

You can choose between 45 starting conditions in total.



Simulation results

DOCKING PORT RELOCATION 27 Nov 2019, 16:23 From port : RASSVET To port : PIRS Duration : 3m:05s Fuel score : 9.8 Contact score : 10  9.9	FINAL APPROACH AND DOCKING 27 Nov 2019, 16:09 Target port : PIRS Range : 50 m ISS attitude : NORMAL Duration : 2m:47s Fuel score : 10 Contact score : 10  10
FINAL APPROACH AND DOCKING 27 Nov 2019, 15:54 Target port : RASSVET Range : 50 m ISS attitude : NORMAL Duration : 3m:32s Failure : collision / no-fly-zone  9.9	FINAL APPROACH AND DOCKING 27 Nov 2019, 15:41 Target port : ZVEZDA Range : 50 m ISS attitude : NORMAL Duration : 3m:31s Fuel score : 9.9 Contact score : 9.9  9.9

Every time a simulation ends, an entry is stored in the [results database](#), reporting the date-time, the selected simulation scenario, the initial conditions, and the duration.

Further information is added depending on the outcome of the simulation:

- In case of *successful docking*, the entry includes scores with respect to fuel consumption and precision at contact, and the average final score.
- In case of *failure*, the entry includes the cause of failure:
 - *Collision/no-fly zone*:
 - Collision with an ISS element (collision).
 - A tentative docking to an ISS docking port different from the designated one (collision).
 - The flying in the proximity of its solar panels or radiators (no-fly zone).
 - *Wrong alignment (at contact)*:
 - The Angle of incidence is greater than 10 deg
 - The delta roll angle is greater than 10 deg.
 - *Range rate out of limits (at contact)*:
 - Range rate not in [-0.20 m/s, -0.10 m/s].
 - *No fuel*:
 - The Soyuz did run out of fuel... and you are basically lost in space.

In the [result table](#) the result entry are presented in descending time order (most recent, first).

It is possible to select an entry and delete it.

Key maneuvers

Short-range approach and docking

When the Soyuz is “facing” the designated ISS docking port, you can go for a [short-range approach and docking](#).

The Soyuz “faces” an ISS docking port when the planes of both the docking mechanisms are almost parallel, and they “look at” each other.

Phase 1: docking port seeking

<i>What</i>	<i>How</i>
The Soyuz is be almost in line with the target ISS docking port that has to be seen close to the center of the periscope view.	$-Y / +Y / -Z / +Z$ as needed.

Phase 2: docking target positioning

<i>What</i>	<i>How</i>
The Soyuz rotates (rolls), so the designated ISS docking port is almost in the up direction and the docking target is almost in the bottom direction. Use the periscope grid and physical elements of the ISS to understand when such a positioning is about to be achieved.	<i>Roll Left / Roll Right</i> as needed.

Phase 3: move forward and keep alignment

<i>What</i>	<i>How</i>
The Soyuz moves towards the docking target, while managing to keep the docking target at the center of the periscope grid.	$-X / +X$ to increase or decrease the distance from the target ISS docking port, as needed. $-Y / +Y / -Z / +Z$ to keep the docking target at the center, as needed. Any attitude correction needed to better align the Soyuz to the docking port.

Fly-around maneuver

The **fly-around maneuver** is the most difficult one you have to master, and it requires some practice.

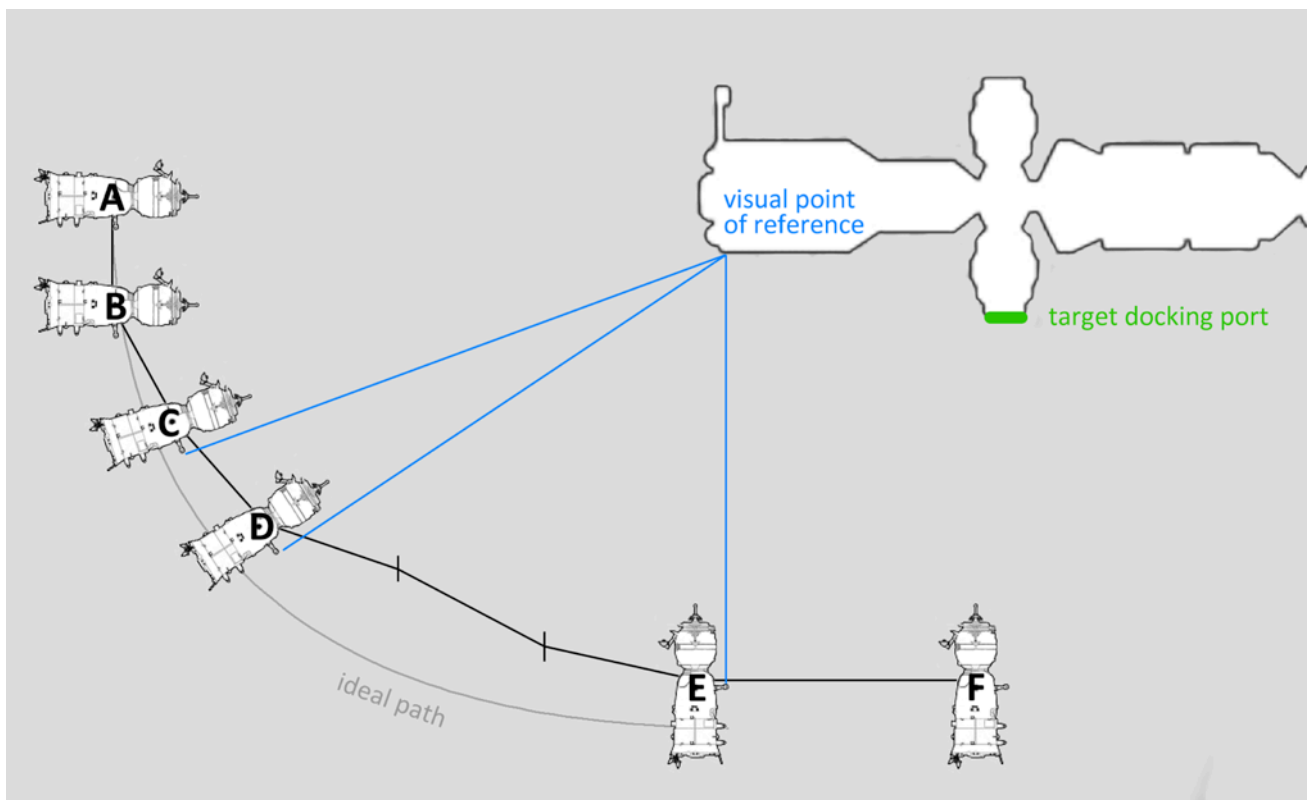
When the Soyuz is not “facing” the designated ISS docking port, a **fly-around maneuver** is necessary. The Soyuz “faces” an ISS docking port when the planes of both the docking mechanisms are almost parallel, and they “look at” each other.

During the **fly-around maneuver** you may need to use the **virtual view** in order to have a visual feedback on the motion.

EXAMPLE

Starting conditions:

- ISS attitude is “normal”.
- The designated ISS docking port is on Pirs module.



Key phases of the fly-around maneuver in this example.

Before point A

After the simulation starts, you move the Soyuz “forward” (translational –X command).

Point A

<i>What</i>	<i>How</i>
The Soyuz stops (range rate = 0 m/s) when the range from the designated ISS docking port is about 30 m.	+X as needed in order to slow down and stop.
The Soyuz now starts to translate downwards.	–Y for about 10 seconds.

Point B

<i>What</i>	<i>How</i>
1 st frontal impulse is required to “circularize” the trajectory.	-X for about ½/1 sec.
The Soyuz rotates upwards, while following a visual point of reference (until point E).	<i>Pitch Up</i> as needed, and continue...

Point C

<i>What</i>	<i>How</i>
2 nd frontal impulse is required to “circularize” the trajectory.	-X for about ½/1 sec.
The Soyuz continues to rotate upwards, while following a visual point of reference (until point E).	<i>Pitch Up</i> as needed, and continue...

Point D

<i>What</i>	<i>How</i>
3 rd frontal impulse is required to “circularize” the trajectory.	-X for about ½/1 sec.
The Soyuz continues to rotate upwards, while following a visual point of reference (until point E).	<i>Pitch Up</i> as needed, and continue...

Between points D and E

<i>What</i>	<i>How</i>
Corrections might be needed to better “circularize” the trajectory.	–X/+X for decreasing or increasing the distance from the visual point of reference, as needed. –Y/+Y for better circularizing the trajectory, as needed.
The Soyuz continues to rotate upwards, while following a visual point of reference (until point E).	<i>Pitch Up</i> as needed, and continue...

Point E

Use a plane (i.e. the back plane of the ISS) as reference in this context; when it is not visible anymore, that means you are at an angle compatible with the designated ISS docking port on Pirs module.

The Soyuz has rotated enough and should now “face” the plane of the designated ISS docking port.

<i>What</i>	<i>How</i>
The Soyuz stops rotating	Release any attitude controller

Between points E and F

You will now experience some residual speed in the Soyuz direction –Y, in this example.

You must compensate by slowing down the motion on the Y-axis, until you have a relative stop when the designated ISS docking port on Pirs is about at the center of the periscope view.

<i>What</i>	<i>How</i>
The Soyuz slows down and stop when almost aligned to the target ISS docking port.	Translational +Y command as needed.

After point F

At this point you are ready for the [short-range approach and docking](#).

About SoyuzSim

For further information and technical support, please contact:

iacopo.baroncini@gmail.com

Your feedback, rating and review are welcome.

Credits

Software engineering, simulation modeling, 3D modeling, graphic design, audio effects:

[iacopo baroncini](#)

Licensed music:

[“Soyuz” by GRZ](#)

www.grzsound.com



for phones and tablets running
Android 8.0 (Oreo) or higher

END OF DOCUMENT