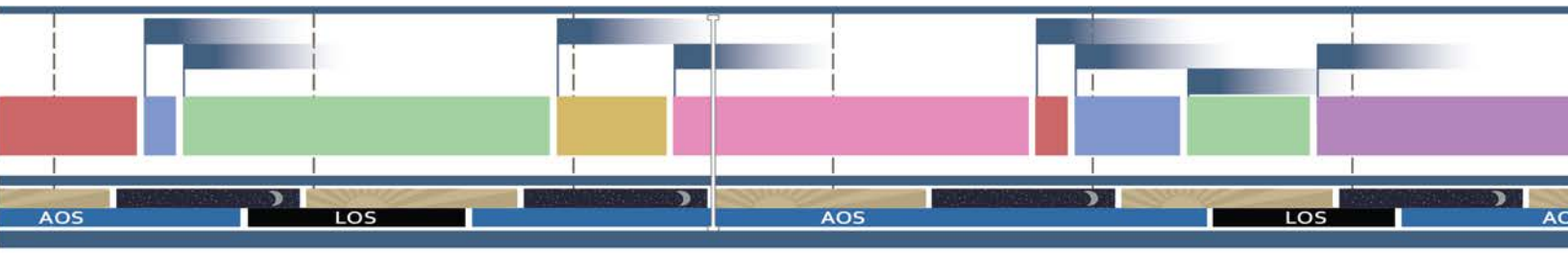


Console Handbook

TOPO

Trajectory Operations Officer

The TOPO flight controller is responsible for planning and tracking the current location and destination of the International Space Station (ISS) and its supporting vehicles. By planning all station orbital maneuvers, the TOPO flight controller can ensure the ISS is not impacted by space debris (trash) which orbits the Earth.

The TOPO flight controller also partners with Russian flight controller, the Attitude Determination and Control Officer (ADCO) flight controller and the United States (U.S.) Strategic Command (USSTRATCOM) to maintain data regarding the orbital position of the ISS.

TOPO

Trajectory Operations Officer

Systems Managed: Trajectory Integration, Orbit Determination, Transitional Maneuvers, Debris Avoidance and Visiting Vehicle Coordination

Trajectory Integration

How is trajectory planned?

The TOPO flight controller works with the Russian Space Agency (RSA), European Space Agency (ESA), and Japan Aerospace Exploration Agency (JAXA), along with commercial U.S. companies, to make sure that all requirements are met when planning the trajectory (orbital path) and operations of the ISS.

The TOPO flight controller works with RSA on ISS position and maneuver planning, visiting vehicle (spacecrafts which dock with the ISS) requirements and efforts in avoiding debris. He or she works with ESA to plan the Automated Transfer Vehicle's (ATV's) trajectory. Last, the TOPO flight controller works with JAXA to plan the H-II Transfer Vehicle's (HTV's) trajectory and the Japanese Experiment Module's (JEM's) navigation. Both the ATV and HTV are unmanned resupply spacecrafts.

Periodically, the TOPO flight controller creates a short-term trajectory plan for the ISS which is used to plan such things as visiting vehicle requirements, reboosts and the scheduling of communication satellites. The flight controller will also provide long-term planning of the ISS position and trajectory.

Orbit Determination

Where is the ISS in orbit?

The TOPO flight controller frequently records the state vectors for the ISS. (A state vector is the position and velocity [speed and direction] of an object at a specific time.) The flight controller also records the state vectors for visiting vehicles, and for the Tracking and Data Relay Satellite System (TDRSS) – a group of communication satellites which allow the Mission Control Center (MCC) to communicate with various spacecrafts.

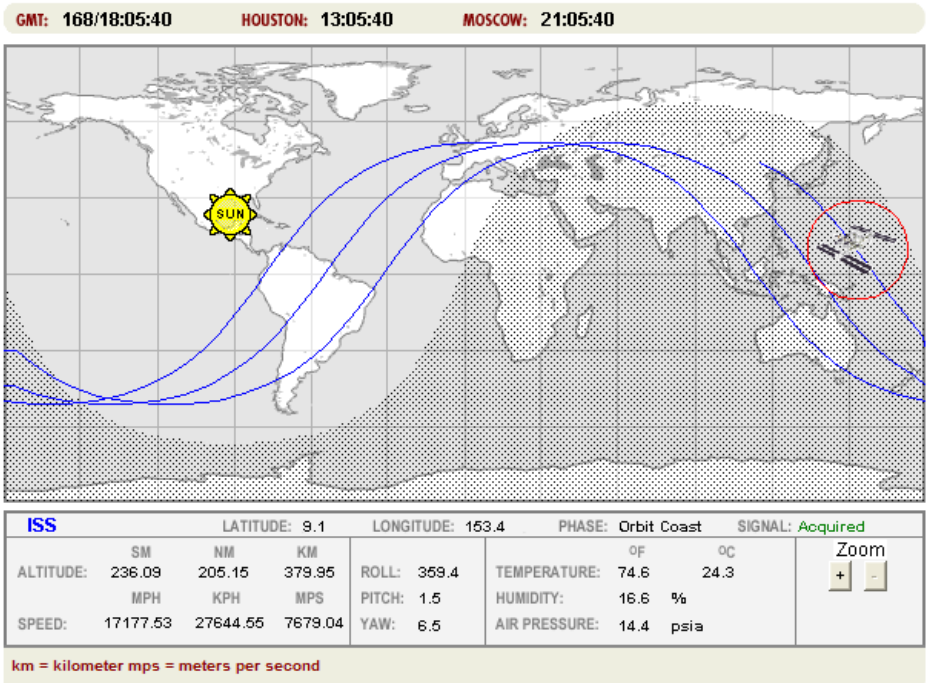
A collection of state vectors over a certain period of time is called an ephemeris. The TOPO flight controller keeps an accurate 15-day ephemeris of the ISS in the MCC.

The TOPO is also responsible for keeping track of:

- times when the ISS will be able to communicate with the Russian MCC (MCC-Moscow), MCC-Houston and amateur radio stations. (These radio stations allow schools to talk with crewmembers on the ISS as a part of the Amateur Radio on the ISS, or ARISS, program);
- times when the ISS is able to see the TDRSS communication satellites;
- sunrises and sunsets on the ISS (the ISS completely orbits the Earth about once every 90 minutes);
- times when the ISS can be seen from Earth;
- the solar beta angle (the angle between the ISS orbit plane and a line to the sun, and shows where the sun is in relation to the ISS and how much of the ISS orbit will be in sunlight);
- orbital elements which define the shape and position of the ISS orbit; and

- orbital data which show the position of the ISS over the Earth on the World Map in the MCC.

Additionally, the TOPO flight controller provides ISS location information to universities and companies which have science research cargo on the ISS, and checks the Global Positioning System (GPS) and Russian state vector sources on the ISS to make sure they agree on the ISS location.



To find out more about the ARISS program, visit http://www.nasa.gov/audience/foreducators/teachingfromspace/students/ariss.html.

To learn when the ISS might fly over your city, visit NASA's Sighting Opportunities website at http://spaceflight.nasa.gov/realdata/sightings.

Translation Maneuvers (Reboosts)

What happens if the ISS falls out of orbit?

The ISS experiences friction from a small amount of atmosphere in orbit. This causes the ISS to lose altitude, or to slip lower in its orbit. To make sure the ISS stays at the correct altitude, large engines on the ISS are used (about once a month) to push it back into a higher orbit. This action is called a translation maneuver, or reboost.

Planning for reboosts begins months ahead of time. Russian flight controllers the U.S. ISS Program and others are involved in planning reboosts, and it is the TOPO flight controller's responsibility to organize the planning. The flight controller coordinates all reboosts, monitors the event while it is being performed and makes sure it was done properly.

To get more information on reboosts and to see a video of the acceleration that the crew experience during a reboost, refer to the Attitude Determination and Control Officer (ADCO) Console Handbook.

Debris Avoidance

How does the ISS avoid collisions?

The ISS travels in low Earth orbit, which is filled with orbital debris (trash). Debris can come from a number of sources, and there is a real risk that any of this debris could collide with the ISS, causing damage.

When the U.S. Strategic Command (USSTRATCOM) identifies orbital debris that could collide with the ISS, it is the TOPO flight controller's responsibility to determine the risk of a collision. The flight controller is notified when any debris object comes within a 4 x 50 x 50 kilometer (km) (2.5 x 31 x 31 miles [mi]) area around the ISS. If any object comes within a smaller area of the ISS (1.5 x 50 x 50 km, or 0.9 x 31 x 31 mi), the TOPO flight controller notifies the MCC and Russian flight controllers. He or she will determine whether the risk for a collision is high, and will begin planning a Debris Avoidance Maneuver (DAM) – a reboost that will move the ISS away from the path of the debris.

Extravehicular Activity (EVA) Support

The TOPO flight controller supports all U.S. and Russian extravehicular activities (EVAs), or spacewalks. The flight controller monitors all jettisoned items (items that are intentionally thrown away by the crew during an EVA) and any overboard items (items the crew accidentally loses during an EVA). If a jettison is planned, the TOPO flight controller performs an analysis ahead of time to make sure that the jettisoned object will not collide with the ISS. If an item is accidently dropped during an EVA, it is the TOPO flight controller's responsibility to estimate the risk of the object colliding with the ISS, and to notify USSTRATCOM and request that they try to find the overboard item.

Satellite Breakups

If an object in orbit has broken into pieces, USSTRATCOM notifies the TOPO flight controller, who then notifies breakup specialists and the Orbital Debris Program Office at Johnson Space Center in Houston. The breakup specialists and Orbital Debris Program Office each run independent analyses to calculate the risk of debris from the breakup colliding with the ISS and then compare the results of their analyses. At this point, the TOPO flight controller will notify the flight control team of the breakup and provide them with the results of the analyses.

Visiting Vehicle Coordination

How are visits planned?

The Russian Space Agency (RSA) has several spacecrafts whose visits to the ISS must be planned in advance. The Russian Soyuz carries cosmonauts, astronauts and supplies to and from the ISS, while the Russian Progress is unmanned and only carries supplies.

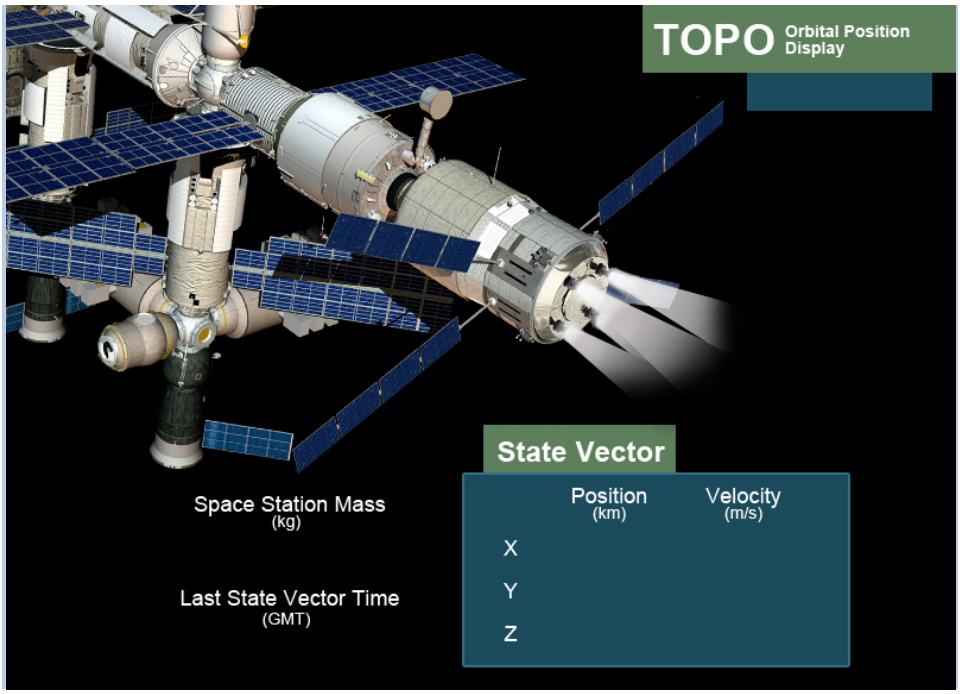
When these vehicles go on a mission, MCC-Moscow provides the TOPO flight controller with their plans for launch, rendezvous (or docking) with the ISS, separation from the ISS and re-entry to Earth. The TOPO flight controller keeps track of each Russian vehicle's position and ephemeris so that MCC-Houston has an idea of where it is. The TOPO flight controller also provides day-of-rendezvous motion plots to MCC-Houston so they can estimate the distance of the Soyuz or Progress vehicle from the ISS and how fast the vehicle is approaching the ISS.

The TOPO flight controller provides similar support for ESA's ATV, JAXA's HTV, and for commercial U.S. vehicles which travel to the ISS, including tracking, docking, separation, communications scheduling and monitoring of possible collisions.

To learn more about the trajectory operations of the ISS, return to the International Space Station *Live!* (ISS*Live!)* website at www.isslive.com. Select “Interact”, and then select “Visit Space Station”.

TOPO Console Display

A wireless signal sends data from the ISS to the Mission Control Center. This data is updated on the TOPO console display. The TOPO flight controller checks the data on the console display to maintain accuracy of the location of the ISS.



Pictured above is a simplified version of the TOPO console display. To view this display, return to the ISS*Live!* website at www.isslive.com. Select “Interact”, and then select “Explore Mission Control”.

Space Station Live Data

Would you like to know more about the live data streaming from the ISS to the TOPO console display? Return to the ISS*Live!* website at www.isslive.com. Select “Resources”, and then select “Space Station Data”. There you will find a table which includes the names and brief descriptions of all the data values used to update the interactive Mission Control Center.

Acronyms and Abbreviations

ADCO	Attitude Determination and Control Officer
ARISS	Amateur Radio on the ISS
ATV	Automated Transfer Vehicle
DAM	Debris Avoidance Maneuver
ESA	European Space Agency
EVA	Extravehicular Activity
GPS	Global Positioning System
HTV	H-II Transfer Vehicle
ISS	International Space Station
JEM	Japanese Experiment Module
JAXA	Japan Aerospace Exploration Agency
km	kilometer
MCC	Mission Control Center
mi	mile
RSA	Russian Space Agency
TDRSS	Tracking and Data Relay Satellite System
TOPO	Trajectory Operations Officer
U.S.	United States
USSTRATCOM	U.S. Strategic Command