

A photograph of the International Space Station (ISS) in orbit above Earth. The station's complex structure, including multiple large solar panel arrays, is clearly visible against the blue and white clouds of the planet. The text is overlaid on the central part of the image.

International Space Station Assembly Lessons Learned

Briefing to International Workshop on On-Orbit Satellite Servicing

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The International Space Station Today

➤ **After nearly 26 years of development and assembly, the ISS is nearly complete**

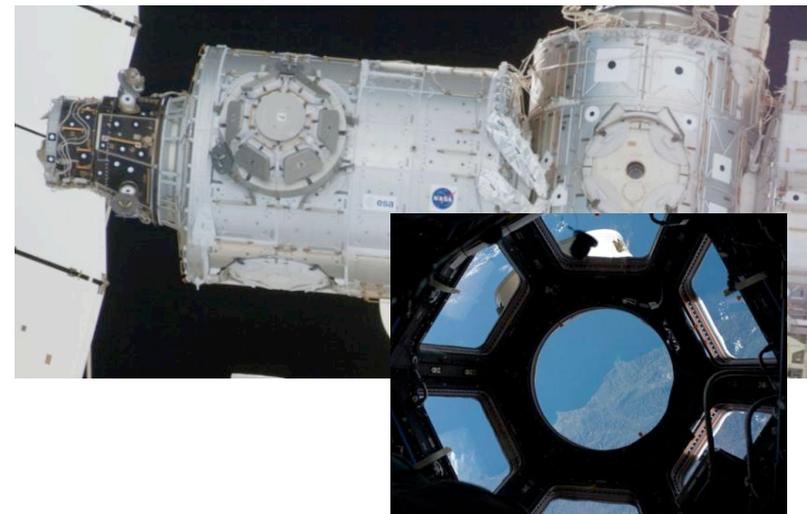
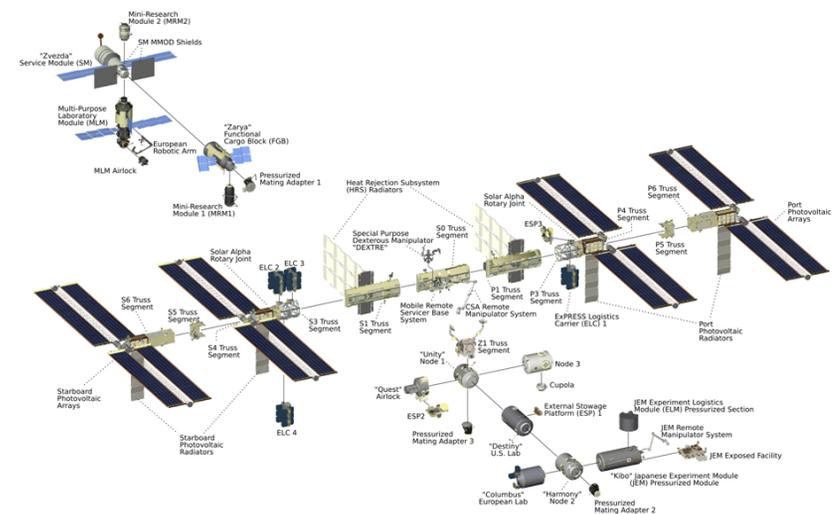
- 35 US and Russian assembly flights
 - 4 to go
- 140 EVA's
- 90% complete by mass
- 90% complete by volume
- 370 km altitude
- 16 Earth orbits each day
- 51.6° inclination covers 90% of world's population

* note: all figures approximate

➤ **In orbit since November 1998 with the launch of the first ISS element *FGB* from Baikonur, Kazakhstan**

➤ **Permanently crewed since November 2000 with Expedition 1**

➤ **6 crew members for nearly one year**





ISS Assembly

No one expected it to take this long
No one expected it to be accomplished
No one expected it to go so well



- **Space Station assembly has evolved over the years**
 - External assembly was more complex and required orders of magnitude more EVA's than the final version
 - If we were to have lost an ISS element, it would have to be replaced or the ISS would have had to be re-designed
 - Dependence on a single launch vehicle significantly set back the program

- **From a top level, if we were again to ever craft a complex mission that required assembly, we should**
 - Limit the number of assembly missions; less than 10
 - Require EVA's only when absolutely necessary

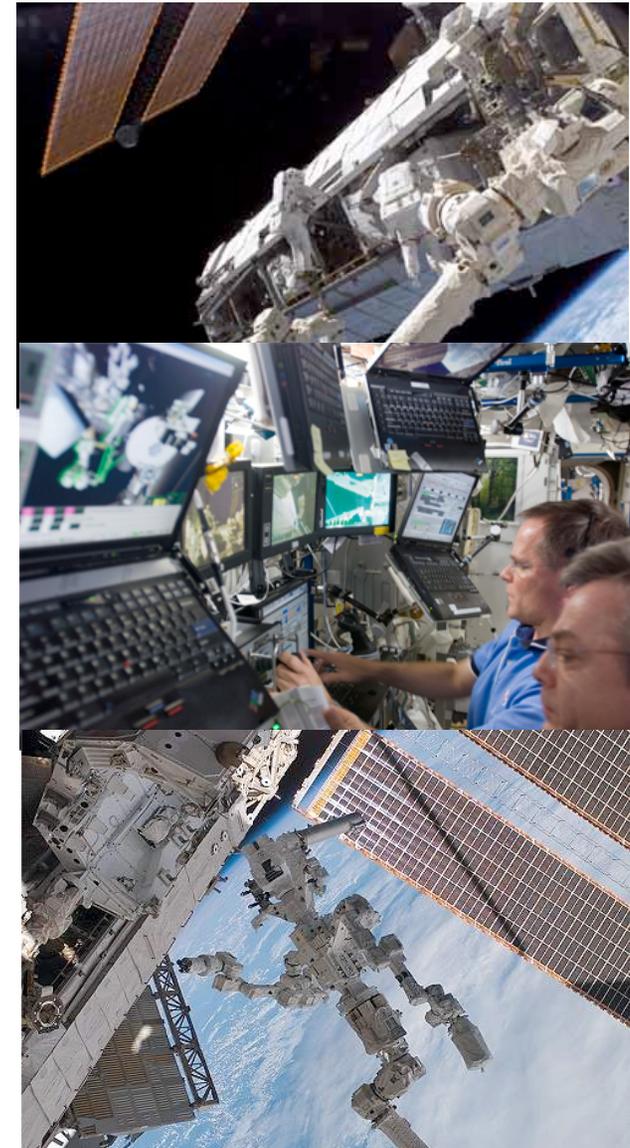


ISS Assembly

- **Human vs. robotic operations require tradeoffs**
 - Safety
 - Amount of planning and training
 - Failure scenarios
 - Cost and schedule

- **For ISS, the investments made in EVA over many years made EVA assembly tasks the preferred mode of operation**
 - SSRMS and SRMS operations were critical to assembly of the large elements – however – nearly 1000 EVA hours to-date were needed to complement robotic assembly operations

- **Most external maintenance tasks were designed to be robotically compatible – but this has not been demonstrated**
 - *Dextre* to demo soon, SSRMS-JEM RMS used for payload transfers – robot to robot handoffs





ISS Assembly Lessons Learned

- **Human operations are very compatible with robotic operations**
 - Demonstrated by many simultaneous EVA and robotic assembly operations
- **Robotic operations can successfully be accomplished remotely without on-board crew**
- **We have performed maintenance tasks on-orbit that were never planned**
 - Maintenance of many ORU's were assumed to be performed on the ground during the design phase



- **Design system and components to be accessible and maintained on-orbit**
 - Even for systems that “don't require” service when originally conceived
- **System design should be paralleled by maintenance and service design activities**



For More Information

ISS Reference Guide

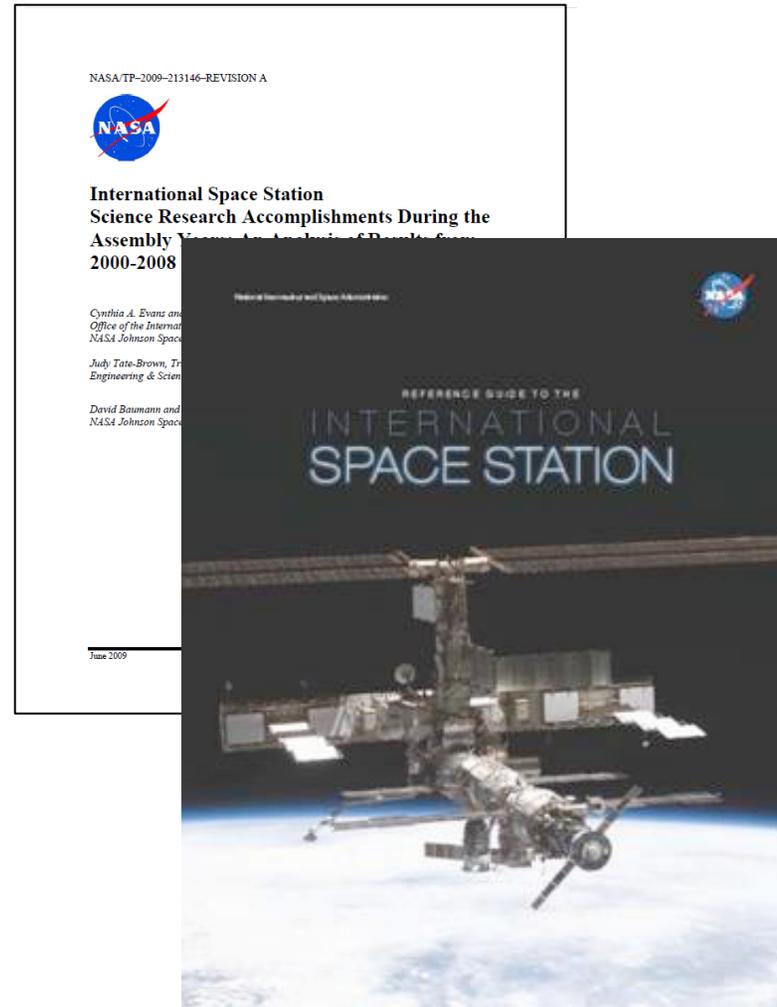
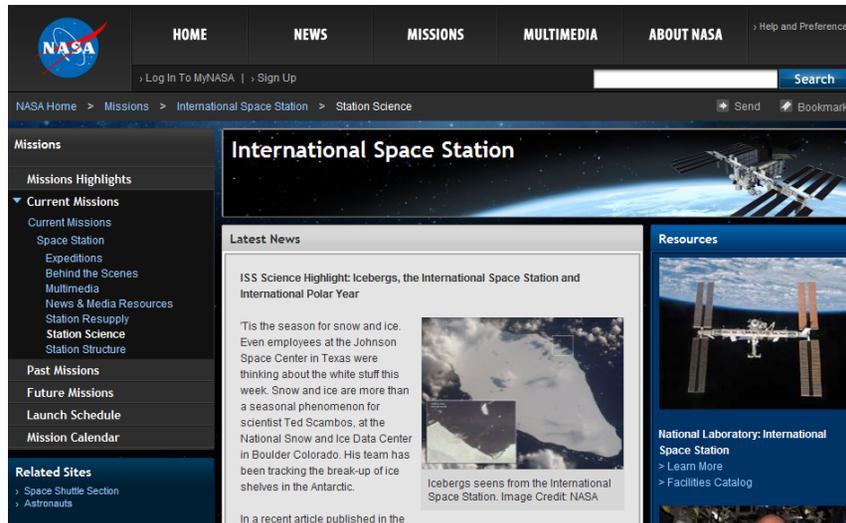
Cumulative Results Reports:

NASA/TP-2006-213146

NASA/TP-2009-213146-REVISION A

Education on ISS 2000-2006:

NASA/TP-2006-213721



Space Station Science Webpages

http://www.nasa.gov/mission_pages/station/science/

Facilities Webpages

http://www.nasa.gov/mission_pages/station/science/experiments/Discipline.html