National Aeronautics and Space Administration

Spektr of Failure:
Mir-Progress Collision

Leadership ViTS Meeting

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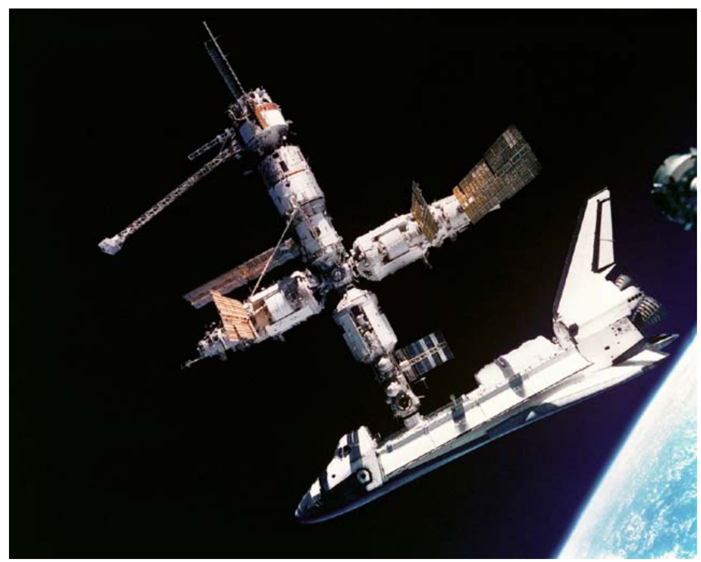
Bryan O'Connor

Chief, Safety and Mission Assurance

Wilson B. Harkins

Deputy Chief, Safety and Mission Assurance



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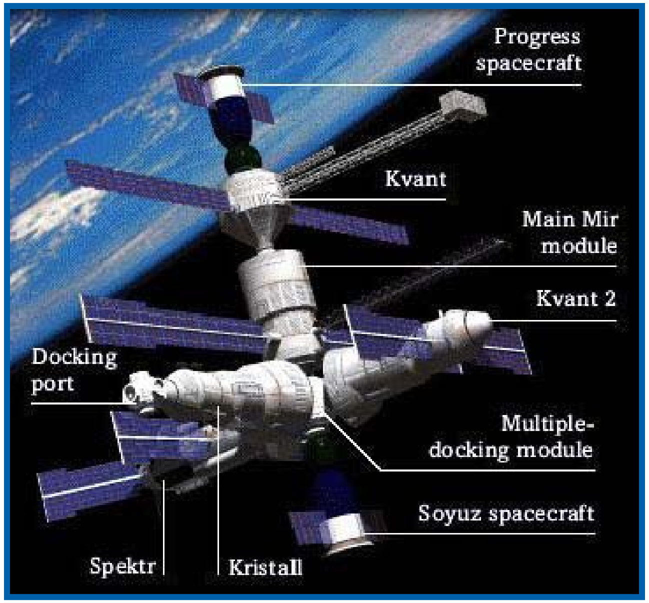
THE MISHAP

On June 25, 1997, an experiment to test manual control mode rendezvous and docking between a Progress automated supply vehicle and Space Station Mir almost turned deadly. Although the three-man crew on Mir controlled the Progress remotely, absence of telemetry data crippled their efforts to steer the spacecraft. Plans to collect speed and range information using a laser rangefinder were thwarted when the crew could not establish visual contact with the vehicle. By the time the spacecraft entered their line of sight, it was too late. Progress slammed into a solar array and ricocheted into Spektr module, sending the station into a slow tumble. The impact punctured Mir's hull and resulted in the first decompression on-board an orbiting spacecraft.



Space Station *Mir*

Progress Docking System

•Automated Progress supply vehicles launched from Baikonur Cosmodrome 3 times each year to deliver fresh supplies and collect accumulated rubbish.

•Progress had been using an automated docking system named *Kurs* since the early 1980's.

•*Kurs* was manufactured by a company in Kiev, but when the Soviet Union fell, Kiev emerged as the Ukrainian capital and the company began charging Russia very high prices for each unit.

•Russia could not afford to pay, so it decided to use an existing manual docking method called Teleoperated Rendezvous Control System (TORU).

Early TORU Flights

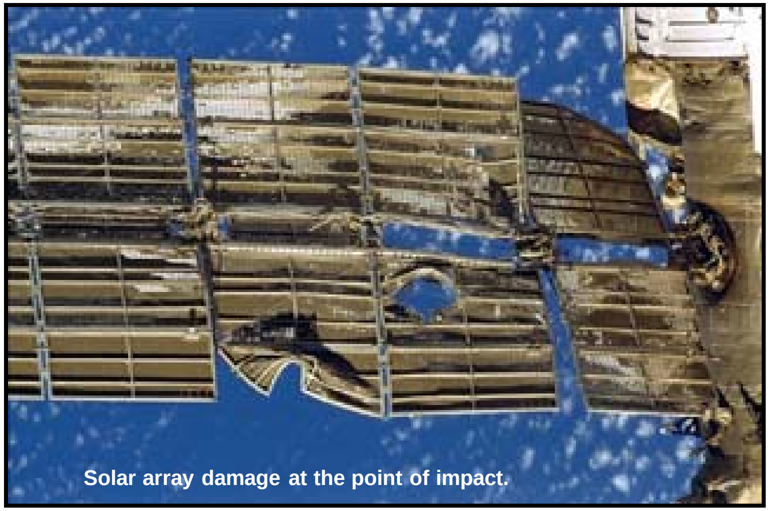
•TORU had only been used to dock a Progress vehicle once as of 1997.

•In March 1997, Russian Mission Control (TsUP) instructed *Mir* crew commander Vasiliy Tsibliyev to perform a docking test using TORU controls on *Mir*.

•RF radiation disrupted his visual feed, forcing him to fly the Progress blind and abort the docking.

•The test resulted in a Near Miss: Progress sailed past the station at a distance of only 200 meters.

WHAT HAPPENED?



Solar array damage at the point of impact.

TORU Test Plan

•TsUP attributed the visual feed malfunction to RF radiation from the *Kurs* antenna, which transmitted telemetry of speed, range, and range rate information.

•To avoid the RF radiation problem on the next test, TsUP decided to switch off the *Kurs* antenna.

•TsUP instructed the crew to obtain speed, range, and range rate data using a handheld laser rangefinder and a stopwatch.

Collision

•On June 25, 1997, the crew began the TORU docking test under remote control conditions for which they had not trained.

•The crew did not have radio contact with the ground during the test.

•*Mir*'s solar arrays blocked the crew's view of the approaching Progress, so their rangefinders were useless.

•Crew commander Vasiliy Tsibliyev applied preplanned braking maneuvers four minutes before the scheduled docking time, but crew members still could not make visual contact with the Progress.

•Ninety seconds before the final docking time, Progress emerged from behind a massive solar array, and the crew saw that collision was imminent.

•Progress collided with a solar array, then ricocheted into *Spektr* module, where it punctured the hull and caused depressurization.

•The crew members rapidly disconnected and cut the cables that wound through *Spektr*'s open hatch, then closed the hatch with an external cover, saving the station and saving their lives.

PROXIMATE CAUSES

Vladimir Utkin, Director of the Central Scientific Research Insititute of Machine Building and astronaut Thomas Stafford headed an investigation (known as the Stafford Commission) which concluded that many factors conspired to undermine crew effort to dock the Progress safely. Foremost among these factors were: 1) A flawed docking procedure that forced the cosmonaut to fly without ground contact and without telemetry of speed, range, and range rate information; 2) The absence of docking simulators on *Mir* that forced the cosmonaut to attempt a manual docking without recent practice; 3) A ground error that overloaded the Progress spacecraft, changing its center of gravity and causing its response to commands to differ from those that TsUP had predicted.

UNDERLYING ISSUES

Economic Pressure

•Because the Russian Space Agency could not afford to pay for the *Kurs* systems, a successful TORU test would liberate funds dedicated to *Kurs* and restore Progress flights, which had been cut down, to their original frequency.

•With these objectives in mind, TsUP added another test in June of 1997, but crew commander Tsibliyev, who had been on board the station since February 1997, was psychologically strained from mission duration and from the close call he had experienced 3 months prior.

•Ground controllers pushed the schedule forward despite this knowledge, and concerned physicians did not speak out because they did not expect to be heard.

Flawed Docking Procedure

•TsUP determined that the *Kurs* antenna interfered with the visual feed signal. Instead of designing an alternate method of transmitting speed, range, and range rate information, they opted to turn off the antenna entirely, robbing Tsibliyev of critical parameters necessary for rendezvous and docking.

•TsUP used a docking approach that caused the vessel to advance at very high speeds (m/s vs. in/s) until the last minute, when brakes would be applied with maximum force. TsUP used this approach because it feared errors would accumulate in the system. Such an approach imposed danger upon the crew, therefore a better option would have been to redesign the docking system rather than to formulate instructions based on a system known to be faulty.

FOR FUTURE NASA MISSIONS

•NASA had not been briefed about the TORU test, and this lack of information kept it from insisting upon performing a ground simulation first. A ground simulation may have shown that Progress' actual center of gravity differed from that which had been programmed into spacecraft guidance.

•The cosmonauts were reluctant to share the technicalities of the TORU system with astronaut crew member Michael Foale, but understanding the technicalities of a system is a crucial element to making rational, informed decisions when off-nominal situations arise.

•This example displays the importance of information sharing. Communication often faces boundaries in the forms of organizational conflicts and sensitivities, but these barriers must be overcome in order to pass on lessons won through experiences such as this one.

***Mir* and shuttle docked together**

•In its rush to implement the TORU system, the Russian Space Agency introduced rangefinders to the situation, but the new components also had a new failure mode – the inability to find the line of sight.

•This example emphasizes the importance of analyzing the failure modes that new systems introduce, accounting for such possibilities, and formulating a means of backup.