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SOVIET AUTOMATED RENDEZVOUS AND DOCKING SYSTEM OVERVIEW

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The Soviets have been performing automated rendezvous and docking for many years. This paper will present an overview and brief history of the Soviet AR&D system, based on the open literature and publicly available sources.

The unmanned Progress resupply ships regularly dock with the current Mir space station. Analysts believe that the earliest docking attempts by the Soviets were made in 1967 with the Soyuz 1 and 2 crafts. Soyuz 1 developed stabilization problems so the docking attempt had to be cancelled. The first successful Soviet docking between two unmanned vehicles was in late October of 1967 when Cosmos 186 and 188 docked in orbit.

Soyuz 3 (manned) maneuvered to within 200 meters of the unmanned Soyuz 2 in October of 1968. Soyuz 4 and 5, both manned, docked and two cosmonauts transferred from Soyuz 5 to 4 via EVA. This represented the first Soviet manned docking. In the US space program, Gemini 8 docked to an Agena target vehicle in March of 1966.

In 1971, an unspecified AR&D system was used to bring the Soyuz 10 spacecraft to within 180 meters of the Salyut 1 space station. A cosmonaut then took over and completed the dock. Several missions were flown in 1973 and 1974 to prepare for the Apollo-Soyuz Test Project flight in July of 1975. For the initial docking, the Apollo acted as the active spacecraft. Later in the mission, the two spacecraft separated and docked again with the Soyuz as the active craft.

A Cosmos 772 (an unmanned Soyuz craft) autodocked to the Salyut 4 space station in September 1975 in order to validate AR&D for future unmanned flights, such as the Progress resupply modules. The first Progress resupply ship docked and transferred fuel to the Salyut 6 in January of 1978.

During the course of the Soviet space program, the autodocking system has evolved. The earlier IGLA system has been replaced with the current KURS system. Both systems are radar-based. The variation in strength between antennas is used for computing relative positions. The active spacecraft has a transponder. From discussions with Soviet engineers, it seems the docking process can be controlled either from the ground or the active (docking) spacecraft's onboard computer.

The chase vehicle flies a constant bearing approach to the target, maintaining a "guidance plane" between the two vehicles. The IGLA system required that a line-of-sight (los) be maintained between the docking faces of the two vehicles. The KURS system, however, does not require los between the two vehicles during closure. The attached diagrams indicate a potential docking trajectories using the IGLA and KURS systems. As can be seen, more fuel can be consumed due to the spacecraft "chasing" the docking port of the MIR.

The docking requires two to three burns to adjust the trajectory. The first is at about 97 km from the station. The approaching spacecraft flies a ballistic trajectory to a point 1.5 km from the Mir. If during the trajectory there is a loss of the main radar system, the onboard computer switches to the secondary (redundant) radar system and continues the docking process.

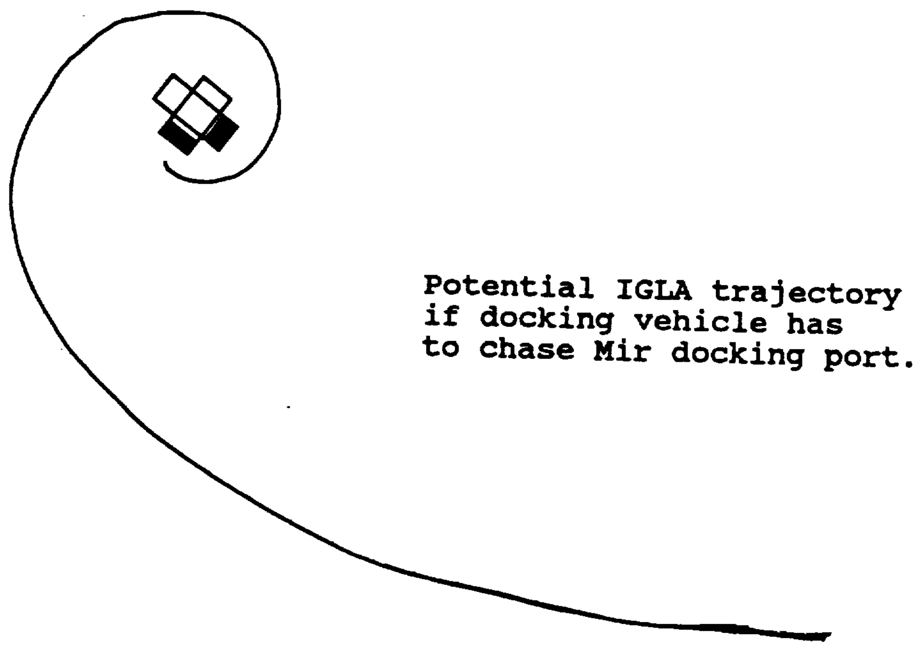
Approximately 100 parameters are checked (once per second) by the onboard computer to insure the craft's systems are working correctly. If any one of these parameters becomes out of range, the docking is aborted. The spacecraft is removed back out to about 100 km and the docking is re-attempted. This involves a delay of about 2 days. Any decision to increase tolerances for a particular parameter is made by the ground control center engineers. This has been done in a few instances. The orbital docking position is chosen based on several factors including the position of at-sea control ships, and the position of the sun so that docking can be performed while not in the Earth's shadow.

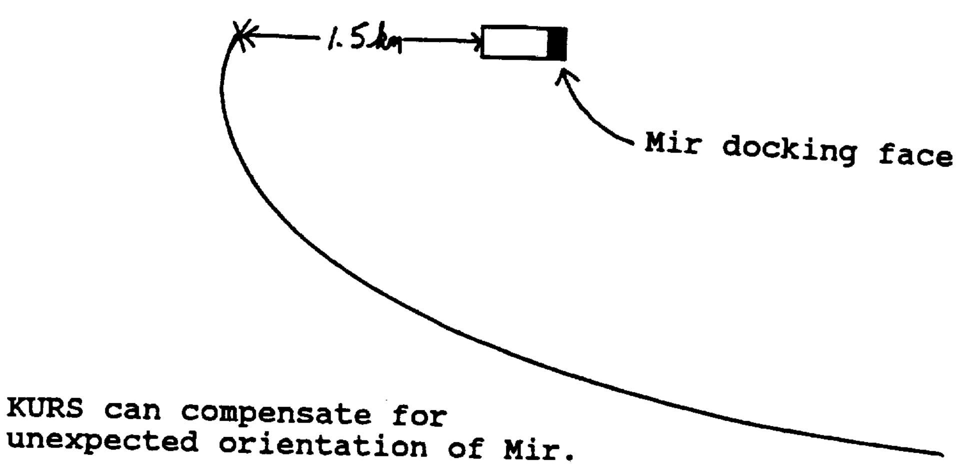
Roll damping of the approaching spacecraft is performed between 5000 and 200 m relative distance. From 1.5 km to 200 m from the target vehicle, one slowing maneuver and angular stabilization are performed. The KURS system is active until just at contact, at which point the engines are used to "push" the spacecraft together. During the last 10 meters of closing between the chase and target vehicles, the relative velocity is about 0.2 m/s. Some parameters at contact between the Mir and an approaching spacecraft are an approach velocity of 0.1 to 0.3 m/s, lateral velocity less than 0.1 m/s with a lateral misalignment of 0.15 to 0.3 m. The angular velocity in roll is kept below 0.7 deg/s, and in pitch and yaw (summed) less than 0.6 deg/s. These numbers are based on documentation of contact between the Mir and a Kvant spacecraft.

Despite the regular autodockings of the unmanned Progress ships with the Mir and Salyut space stations, autodockings of manned vehicles with the stations have not been overly successful. The Soyuz T spacecraft was designed for full AR&D, however the autodock system has been routinely overridden in order to perform manual docking. Computer data overloads, loss of radar signal and antennae failures have been cited as reasons for failure of the AR&D system.

It is likely that the Soyuz T spacecraft incorporated the IGLA system, and the later Soyuz TM and Progress M series craft incorporated the KURS. The Mir has both systems installed. The first Soyuz TM dock occurred in May of 1986, while the first Progress M docked in September of 1989.

POTENTIAL TRAJECTORIES





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