THE SOYUZ SPACECRAFT TODAY AND TOMORROW

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Abstract

The Soyuz spacecraft has been in use since the late 1960s. To effectively meet the needs of various past programs, the Soyuz has undergone four main evolutions. Today, the projected near-future increases in manned space flight activity may serve as a catalyst to design a completely new and larger spacecraft based on the proven flight heritage of Soyuz technology. An advanced Soyuz spacecraft derived from the present day model has potential as a component to, reusable launch vehicle (RLV) and other programs. To leverage global aerospace manufacturing skills, and gain access to international markets, the advanced Soyuz could be manufactured internationally using private funding.

Introduction

Lockheed Martin's and NASA's bold effort to develop and test fly the X-33 will hopefully provide the fledgling space payload market with access to the VentureStar, a much touted modern-day equal of America's first transcontinental railroad. However, steps must be taken to ensure that there is a vibrant research and commercial user market waiting to use the VentureStar. It is in the space transportation industry's best interest to provide the user market with better access to space during the construction of the International Space Station (ISS) and development of the VentureStar. The main reason for doing this is that a healthy user market will serve as a strong advocate force for the timely completion and delivery of the VentureStar.

The X-33's and VentureStar's operational goals are ideal and based on lessons learned from aircraft, expendable launch vehicles and Space Shuttle operations. However, there is no guarantee that VentureStar will not follow the same troubled and costly path as the Space Shuttle program. This is the risk and challenge of relying on technological quantum leaps to achieve the ambitious goal of a single stage to orbit RLV.

Space Shuttle and eventual RLV operations should be augmented to ensure that round-trip-access to orbit capacity fosters growth in the private sector and government payload market. This is the perfect role for a third space system based on Soyuz-derived spacecraft technology. This enlarged, advanced Soyuz spacecraft could safely and reliably ferry six or more people to and from low earth orbit (LEO).

The main operational advantage of the advanced Soyuz over the Space Shuttle and RLV would be it's ability to fly extended missions in orbit. Additionally, an automated, unmanned variant of the evolved Soyuz could also be flown for long-term microgravity missions, or to deliver cargo and consumables to LEO. In fact, the mission roles of the RLV and the advanced Soyuz could be complementary.

One example of an advanced Soyuz and RLV combining their mission capabilities is the following: An RLV could launch and recover the advanced Soyuz in orbit, freeing the RLV to service several other missions on orbit simultaneously. Theoretically this would reduce launch costs, and maximize flight opportunities for users while minimizing advanced Soyuz refurbishment costs.

If an emergency were to occur with an advanced Soyuz in orbit the spacecraft could return to Earth without having to wait and rendezvous with the RLV. Additionally, if the entire fleet of RLVs were to become grounded, advanced Soyuz flight operations could continue by using expendable launch vehicles.

General Production Issues

Inevitably the primary criticism of a program to build advanced Soyuz spacecraft for international customers, is that it would be a solely Russian manufactured and controlled program. One possible solution to this issue may be to create a private multinational corporation comprised of aerospace companies which have the necessary skills to manufacture major spacecraft components reliably and economically. Plus if the corporate partners structure this spacecraft company correctly, it may be feasible to solicit and obtain investment capital to fund the program.

Private investment in the program would eliminate the need for governments to provide development funding in the program. Governments which become users of an advanced Soyuz could offset launch and operations costs, by launching the spacecraft on domestic launch vehicles.

Soyuz History

The proven history and evolution of the Soyuz makes a strong case for using it as a technological foundation for a new spacecraft design.

The development of the Soyuz spacecraft was initiated under the supervision of RSC Energia's founder and first General Designer, Sergei P. Korolev, in the early 1960s, immediately following the successful flight of Yuri S. Gagarin aboard Vostok 1.

The Soyuz was from the very beginning conceived as a multipurpose manned spacecraft which should perform the following basic mission objectives: fly an extended mission in orbit with a crew of up to three; perform orbital maneuvers; perform automated/manual approaches and dockings; facilitate extravehicular activities (EVA) by cosmonauts; and execute a controlled descent into the atmosphere.

In accordance with the design approach adopted in Russia for the development of manned vehicles, the Soyuz was created with the capability for both automatic and crew-piloted flight. Flight tests of the Soyuz spacecraft began in 1966, first using unmanned spacecraft and then manned vehicles. Unfortunately, the first manned test flight of a Soyuz spacecraft, Soyuz 1, was a failure, killing the cosmonaut test pilot V. M. Komarov. The failure of Soyuz 1 was the result of a previously undetected imbalance in the reentry capsule. This imbalance caused the capsule to spin during Earth decent and resulted in a deployment failure of the parachute system.

After the initial spacecraft defects were corrected and Soyuz operations were restarted. The first modifications to the original Soyuz design began in the late sixties. These first modifications were intended to maximize the Soyuz spacecraft as a space station transport vehicle for delivery of crews to the Salyut long-duration orbiting space station. Further modifications took place in the early 1970s, adapting the Soyuz for docking missions with the Apollo spacecraft in support of the Apollo Soyuz Test Project .

The Soyuz T, a second design modification on which work was begun in 1969 and completed only at the very end of the seventies, became what is known as the basic Soyuz model, the Soyuz T first flew in 1980. The new Soyuz T spacecraft was enhanced significantly. It carried a new flight computer and a redesigned control and spacecraft health monitoring system. A number of other systems on the Soyuz T were also upgraded. During the Soyuz T redesign improvements were made to the design and technology of spacecraft manufacturing and testing processes in the production plant.

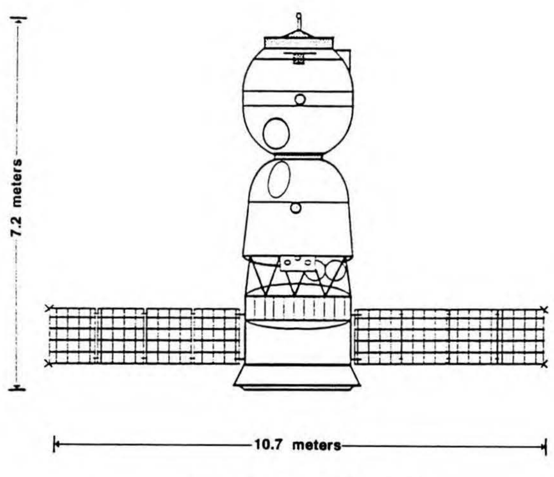

Figure 1: The Soyuz TM Spacecraft

The Soyuz TM (Fig. 1) was completed in 1986, featuring a new flight radar system and further upgrades to the control system. Soyuz TM is the most recent generation of the evolved Soyuz spacecraft design and is used to support the Mir

Space Station program today. Soyuz TM-25 is presently docked to the Mir Space station and Soyuz TM-26 is planned to replace it this August.

A Soyuz Variation

The automated Progress cargo transport vehicle was developed in the mid-1970s. This unmanned cargo vehicle is based on the design and systems of the Soyuz spacecraft. The first mission of a Progress was conducted in 1978, and included an automated docking with the Salyut-6 space station. The Progress-M space cargo vehicle made it's first flight in 1989 and employed system upgrades from the Soyuz T and Soyuz TM spacecraft.

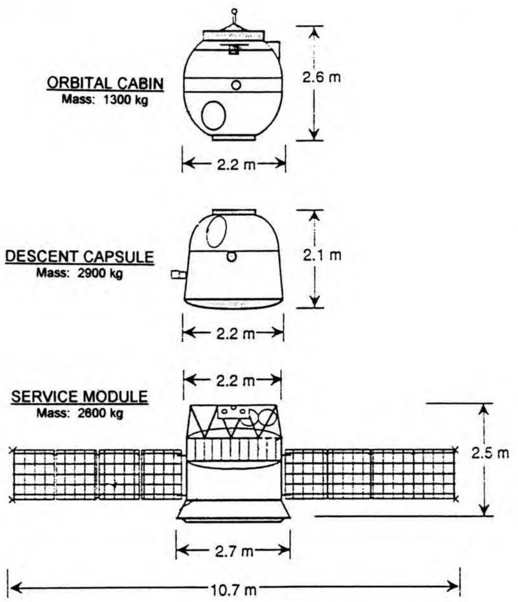

Figure 2: Soyuz Spacecraft Modules

Main Features of the Soyuz Spacecraft

At present, the Soyuz is an expendable vehicle which is made up of three main modules (Fig. 2):

1. The descent capsule accommodates the crew during injection into orbit and descent to Earth. It also serves as the cockpit for control of the spacecraft during docking, maneuvering and other operations. All vital equipment is installed aboard the descent capsule. Aboard the Progress M a large fuel tank system used in refueling space stations replaces the descent capsule.

2. The service module contains the reaction control system (RCS), the main engine, solar arrays and other equipment and instruments used during orbital flight.

3. The orbital cabin contains equipment used by the cosmonauts during orbital flight, primarily the life-support systems. The docking assembly is installed in the top section of the orbital cabin along with the flight radar antenna. The orbital cabin can also serve as an airlock for performing EVAs. The Progress M spacecraft uses the Soyuz orbital cabin as a cargo bay for supplies to be removed by the cosmonauts and brought aboard the space station.

Soyuz Main Systems

Practically every generation of the Soyuz has included the same main systems to support spacecraft operations during launch, orbital flight and return to Earth. The continued evolutionary development of these systems, is a key factor in the high reliability of the overall Soyuz spacecraft. These systems are listed below:

-Electric Power System
-Life Support System
-Thermal Control System
-Automatic Equipment Control System
-Motion Control System
-Radio Communications Systems, for Voice Communications, Telemetry, Television & Command Radio Links
-Telemetry Information Collection System
-Docking System
-Combined Propulsion System, which includes the Main Engine & Reaction Control System
-Landing System
-Descent Control System
-Emergency Rescue System

Present Soyuz Design Restrictions

Here are the main limitations which effect the capabilities of current and future programs using the Soyuz spacecraft. These limitations will have to be addressed in the development of a larger spacecraft based on the Soyuz design.

- Weight restrictions which are determined by the capabilities of the launch vehicle
- Volume restrictions inside the descent capsule
- 180 day maximum orbital mission duration docked to a space station
- Speed and characteristics of maneuvering in orbit, which is determined by the fuel reserve in the reaction control system
- Components that require modernization
- Increased costs of individual subsystems
- Complexity and considerable time involved in

preparing for Earth descent

Prospects for a Reusable Advanced Soyuz Spacecraft

It is well known that the Soyuz is an expendable vehicle, and two of its modules, the service module and the orbital cabin, are destroyed during Earth reentry. While the descent capsule is recovered, it is not used again and spends its post flight days on Earth in laboratories or museum exhibits.

Before Perestroika and the new era in Russia, not a single instrument which returned from space in a descent capsule was used again. However, this policy has recently been changed due to the present economic situation of the Russian space program. To conserve funds we now refurbish equipment after it is returned from orbit aboard the Soyuz or Space Shuttle.

The new recycling policy is one of many data points which indicates that development of a reusable descent capsule suitable for repeated use is technically possible and may be economical. Such a project has been studied on a conceptual basis at RSC Energia, and the list of technical problems which must be solved has been defined. It will require substantial modification of the original Soyuz design, and additional research and development must be performed. Certainly RSC Energia has the experience and the resolve to carry out this work once the demand or market for such a spacecraft has been identified.

However, it must be said that developing a Soyuz-derived reusable spacecraft is not a project that is urgently needed at present, even though a market for such a vehicle may exist. Again our driver for the need to reuse equipment is mainly fueled by the economic situation within the space industry of Russia. Resolution of the previously discussed Soyuz design restrictions is a more important issue at the present time.

Near Term Soyuz TM Improvements

Our analysis indicates that in the very near future when the International Space Station has been deployed, and its operation has begun, the Soyuz spacecraft will have to satisfy the following requirements, which are presently not being met:

- A wider range of anthropometric parameters for the crew members (the ability to accommodate tall people in the decent capsule). This refinement is presently being worked on under a contract from NASA and the Russian Space Agency;

- Increase the Soyuz TM mission time in orbit. Research and development is continuing at present, and work has begun on ways increase the docked orbital lifetime of the Soyuz TM to one year. The most critical subsystem limiting Soyuz TM orbital life is the reaction control system for the descent capsule, which operates on hydrogen peroxide. Other limiting elements are the storage batteries and certain avionics systems.

- Improve the atmospheric descent control system. An ideal improvement to this system would be maneuverability during landing. A steerable parafoil is one candidate solution to this problem.

- Update the electronic parts, especially in the avionics. This would help reduce component dimensions, weight and eliminate dependence on parts that are obsolete.

- Increase the efficiency of production and testing processes to reduce the overall cost of manufacturing the Soyuz TM.

Given the highly successful history of the Soyuz spacecraft program. It is important that the Soyuz is recognized as an asset to continued international development of space. In its present state the Soyuz program has financial, technical and political issues that must be resolved. This is necessary if a new spacecraft based on the Soyuz is to be constructed to meet the space transportation needs of the next millennium.

The Soyuz path makes sense when one compares the problems of building an advanced Soyuz with the uncertainties of developing, building and testing a spacecraft from scratch.