

"PROGRESS SATELLITE: AN AUTOMATIC CARGO SPACECRAFT

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16. Abstract The article discusses the requirement for resupplying long term orbital space stations. It then describes the operation of "Progress" (an unmanned automatic resupply spacecraft). It concludes that the development of "Progress" is a major contribution of Soviet science to domestic and world aeronautics.			
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"Progress" Satellite: An Automatic Cargo Spacecraft

Truck, fuel tank, tow--these are the functions of the new brainchild of Soviet science and technology designed to serve long-term orbital stations. The orbital stations with changeable crews--man's trunk line into space. In the Soviet Union reliable, constantly improving stations in the series "Salyut" have been made. Highly efficient methods and means of making observations from space have been developed. In numerous flights the base spacecraft "Soyuz" has been finished off and comprehensively tested as a means of supplying crews to the station. Twice, in flights of "Salyut-3" and "Salyut-5" the results of the orbital work were sent to earth by an automatic re-entry apparatus. The fulfillment of loading operations in space--the next step on this path.

The creation of a freight transport craft to guarantee the operation of orbital stations is an objective need. From year to year man's activity in space is activated. The duration of the active existence of orbital stations is increasing ("Salyut-4" for example, operated in space over two years). In the process of operation of the stations the cosmonauts consume the supplies of produce, water, protein, bed linens, means of personal hygiene, and oxygen that have been supplied on board. The changeable elements in the system of life support are consumed: cartridges of air regeneration, all possible filters, absorbers, elements of electrical equipment, and communication. The supplies of movie and photo film are exhausted. The quantity of fuel for the sustainer is decreased, which periodically is engaged to maintain the altitude of the station's flight, for numerous small engines that implement its orientation and stabilization. Gradually the pressure drops in the compartments as a result of sluicing of wastes and discharges of the crew into open space. Certain equipment exhausts its operating life and requires replacement.

During the operation of the orbital station everyday 20-30 kilograms of different substances are consumed. It is not difficult to calculate what enormous supplies the operation of the station requires, say during a year. Without filling of the on-board supplies during the flight its operation is practically impossible.

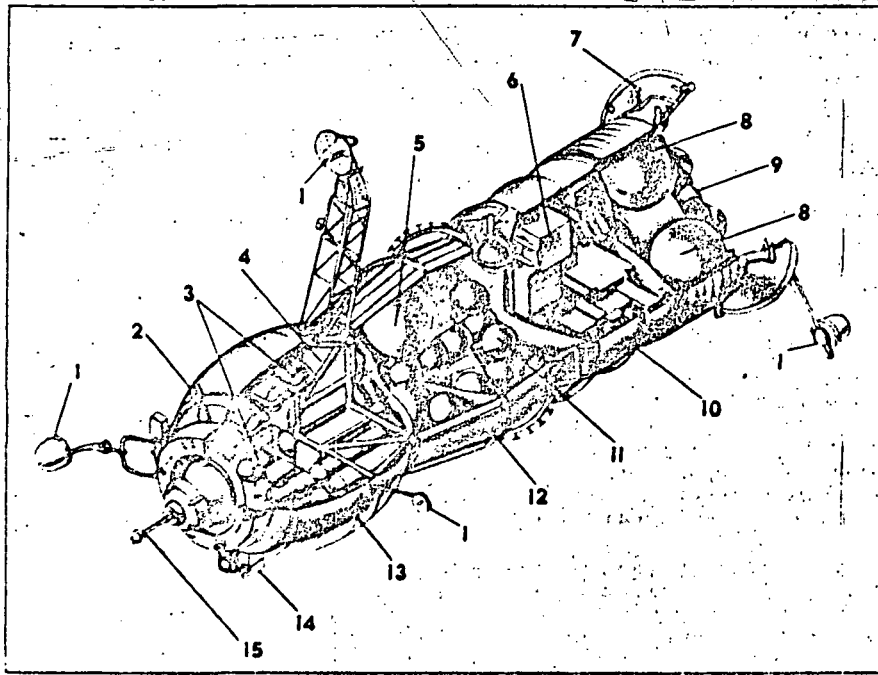
In addition in the flight a need can develop to conduct some studies and observations not planned for by the assignment. And this requires new equipment and subjects of study.

Thus the creation of a loading transport craft capable of supplying in orbit equipment to replace that which is no longer in service or has exhausted its operating life, of filling up consumed supplies of produce and fuel, has been dictated by the urgent need, and striving to increase the economic efficiency of orbital stations, and the flexibility of observations made in space.

The craft "Progress" is unmanned. This means that the part of the payload that is set aside for cosmonauts can now be given to freight. On board the craft chairs are not needed, control panels for the craft, complicated, and what is most important--heavy equipment of the life support system. In addition the designers decided to make it nonreturnable. This made it possible to make an even greater increase in the load capacity of the craft due to the heat-protecting screen, parachute systems, soft landing engines, and systems of controlling the descent.

"Progress" has been created on the basis of "Soyuz." In order to save resources and reduce the periods of development many systems of "Soyuz" have been used that prove to be good in operation and that meet the tasks of the new craft. The traditional arrangement of the craft has been kept. "Progress" also consists of three compartments: instrument-aggregate; fuel, located where

previously the re-entry apparatus was located; and freight, that occupies the place of the living compartment on "Soyuz" (fig. 1).



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Figure 1. Freight Craft (Progress)

Key:

1. Antenna of radio engineering system of convergence and docking
2. Light index
3. Freight containers
4. Elements for fastening cargo within compartment
5. Tanks with fuel transported in orbit
6. On-board service systems
7. Engines of orientation
8. Fuel tank of engine unit of craft
9. Sustainer
10. Instrument-aggregate compartment
11. High pressure gas cylinders
12. Fuel compartment
13. Freight compartment
14. Television camera for external scanning
15. Active docking aggregate

One can say about the instrument-aggregate compartment that this is an analogous compartment of "Soyuz" that has been modified only to improve the

reliability of the system which was inevitable due to the lack of a crew on board.

The main compartments of the craft, fuel and freight, are completely new. Both of them are hermetically sealed. The freight compartment has a docking assembly with a manhole for access into the craft of the crew of the orbital station. In contrast to the "Soyuz" the docking assembly of "Progress" has additional automatic hydraulic connectors designed to hermetically connect the fuel lines of "Progress" and "Salyut" during the docking. The freight compartment is 6.6 m³ in volume and is equipped with shelves for dry cargo in packages and containers. Up to 1300 kg of different cargo can be put into orbit in it--instruments, scientific apparatus, containers with products and tanks with water, changeable components of the life support system. The system of fastening of the cargo provides for preservation of the necessary center-of-gravity position of the craft, and makes it possible to rapidly release certain containers during unloading. Here rapidly opening locks and bolts were used which free the cargo by a turning of the head only a quarter of a turn. The normal atmospheric pressure is maintained in the compartment and the required temperature is kept (from +3 to +30° C).

On the outer surface of the freight compartment are located antennas of the radio engineering system of convergence, television cameras of external survey (of them one looks forward to the station, and the second--to earth), one of three light indices by which the crew of the station judges the correctness of the mutual position of the apparatus during docking (the two others are located on the fuel compartment). On the outside are also located fuel lines and oxidizer lines from the fuel compartment of the craft to the hydraulic connectors of the docking device.

Nevertheless the main concern of designers became the fuel compartment. If the operations of supplying dry cargo do not have any principal innovation, then the transfer of fuel from one apparatus to another in orbit is a completely new task. Here it was necessary to guarantee the reliable hermetic sealing of the hydraulic connections of the craft and the station, to develop technology of transporting fuel components on connected lines, that excludes the falling of gas inclusions into the engine unit of "Salyut", and to provide for long-range-automatic control of all the operations in light of the high aggressiveness and toxicity of the fuel, control of the process of refueling, and much more.

Design-wise the compartment was made in the form of two truncated cones connected to each other by large bases. Within the compartment, on special frames spherical tanks are located with the fuel component--two with fuel and two with oxidizer--of total weight about 1000 kg, and gas cylinders with nitrogen (or air) used to displace the fuel components during transfer, as well as to fill the expended supplies of air on the station. Control of temperature and pressure has been stipulated in the fuel tanks and in the gas cylinders during storage and refueling, the hermetic sealing of connected lines, as well as the blowing through of the lines before unlinking of the apparatus. The refueling of the station is controlled by a command radio line with earth or with the crew of the station with the help of a special panel and graphic panel located in the region of the central post of the station.

The operation to transfer components requires preparation for it not only of a refueling system of "Progress", but also of the fuel system of "Salyut." A simplified scheme of refueling is shown in figure 2. The system of fuel supply to the engine unit of "Salyut-6" is forced. This means that fuel from the tanks is forced into the line by compressed gas under high pressure. In

order for the liquid and gas not to mix the tank is divided into liquid and gas cavities by a corrosion-resistant elastic membrane (bellows). During loading on earth this membrane is squeezed by the pressure of the fuel towards the opposite wall of the tank, and the liquid thus fills the entire tank. In its gas cavity there is a connecting pipe along which the compressed nitrogen passes from the high pressure cylinders (about 200 atmospheres) through the reducer. By acting on the flexible membrane the nitrogen is also precisely a source of energy that guarantees the entrance of the components into the combustion chamber.

Thus in the gas cavities of the "Salyut" tanks there is always pressure (on the order 20 atmospheres) which does not make it possible to immediately begin transfer of components from the fuel compartment of "Progress." In order to eliminate this resistance the designers placed on the station a fairly solid (by space measures, naturally) compressor with engine power 1 kilowatt. Nitrogen from the fuel tanks of "Salyut" is pumped out by this compressor and returned to the cylinders. And since the compressor is fed from a buffer battery that requires periodic recharging from solar batteries the process of preparation for refueling occupies considerable time.

The actual transfer of fuel components lasts for a much shorter time. For this it is sufficient to open the necessary valves on the connected fuel line (fuel or oxidizer) and feed the compressed nitrogen into the tanks of "Progress" (in principal analogous to the tanks of "Salyut"). The refueling ends with the removal (blowing through, evacuation) of the fuel component from the lines to prevent the aggressive liquid falling on the structural part of the station and the craft during unlinking.

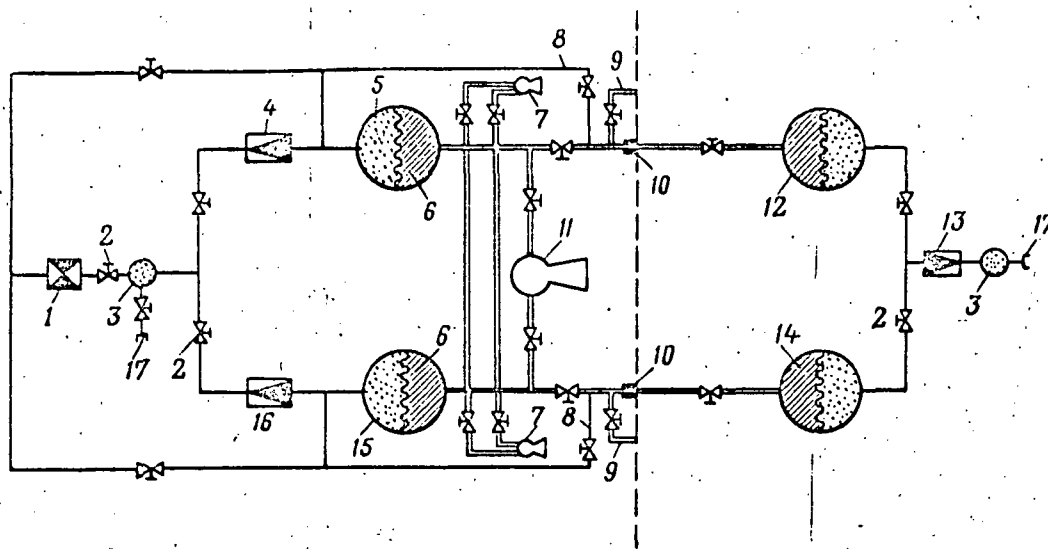


Figure 2. Simplified Scheme of Refueling Orbital Station with Fuel.

Key:

- | | |
|---|--|
| 1. Compressor | 9. Line of evacuation for connected fuel line |
| 2. Shut-off fittings (vent, valve) | 10. Impermeable assemblies of hydraulic connectors |
| 3. High pressure cylinder of system for fuel component displacement | 11. Sustainer |
| 4. Reducer of line for supercharging fuel tank | 12. Fuel tank (on craft) |
| 5. Fuel tank (on station) | 13. Reducer of system for fuel component displacement |
| 6. Elastic partition (bellows) | 14. Oxidizer tank (on craft) |
| 7. Low thrust engine | 15. Oxidizer tank (on station) |
| 8. Line for blowing through connected fuel line | 16. Reducer of line for supercharging oxidizer tank |
| | 17. Connecting pipe for filling high pressure cylinder |

At the end of the joint work with station the craft "Progress" can be used to lift "Salyut" to a higher orbit, that is to fulfill the function of a tow. Here not only the engine unit of "Progress" is used, but also its system of orientation to control the spatial position of the entire complex.

And finally, the new craft has yet another duty--to help the crew of the station to get rid of the clutter on the station. In the freed freight compartment of the craft the cosmonauts place used equipment, cartridges of the

regeneration system, empty water containers, all possible containers--everything that is no longer needed on the station and at the same time does not require return to earth. This reduces the consumption of air in the station during sluicing of wastes.

"Progress" having unlinked from the station engages the deceleration engine, and without separating enters the dense layers of the atmosphere where it ends its existence. The creation of the automatic freight craft "Progress" to service lengthy operating orbital stations is a major contribution of Soviet science to domestic and world astronautics.

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