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SPECS—ORBITAL DEBRIS REMOVAL

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OVERVIEW

The debris problem has reached a stage at which the risk to satellites and spacecraft has become substantial in low Earth orbit (LEO). This research discovered that small particles posed little threat to spacecraft because shielding can effectively prevent these particles from damaging the spacecraft. The research also showed that, even though collision with a large piece of debris could destroy the spacecraft, the large pieces of debris pose little danger because they can be tracked and the spacecraft can be maneuvered away from these pieces. Additionally, there are many current designs to capture and remove large debris particles from the space environment. From this analysis, it has been decided to concentrate on the removal of medium-sized orbital debris, that is, those pieces ranging from 1 cm to 50 cm in size.

The current design incorporates a transfer vehicle and a netting vehicle to capture the medium-sized debris. The system is based near an operational space station located at 28.5° inclination and 400 km altitude. The system uses ground-based tracking to determine the location of a satellite breakup or debris cloud. These data are uploaded to the transfer vehicle, which proceeds to rendezvous with the debris at a lower altitude parking orbit. Next, the netting vehicle is deployed, tracks the targeted debris, and captures it. After expending the available nets, the netting vehicle returns to the transfer vehicle for a new netting module and continues to capture more debris in the target area. Once all the netting modules are expended, the transfer vehicle returns to the space station's orbit where it is resupplied with new netting modules from a space shuttle load. The new modules are launched by the shuttle from the ground and the expended modules are taken back to Earth for removal of the captured debris, refueling, and repacking of the nets. Once the netting modules are refurbished, they are taken back into orbit for reuse. In a typical mission, the system has the ability to capture 50 pieces of orbital debris. One mission will take approximately six months and the system is designed to allow for a 30° inclination change on the outgoing and incoming trips of the transfer vehicle.

TRANSFER VEHICLE

The transfer vehicle is the part of the debris removal system that moves the nets, netting vehicle, and netting modules close to the debris that is targeted for capture. A basic layout of the vehicle is shown in Fig. 1.

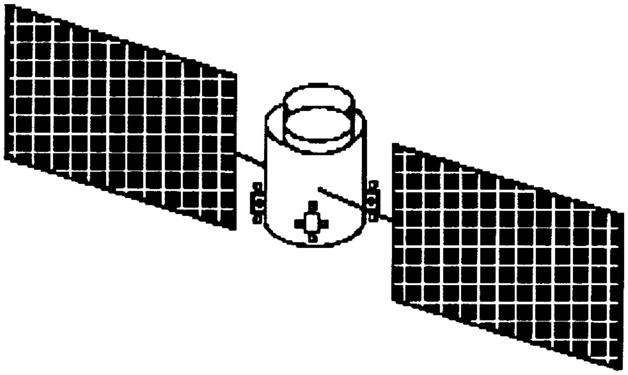

Fig. 1. The layout of the transfer vehicle.

The transfer vehicle is capable of 30° of inclination change on both legs of the trajectory. To accomplish the large inclination change without massive amounts of fuel, the transfer vehicle uses ion engines for thrust. This allows the fuel to be reduced to 10% of the amount that would be used if chemical engines were used. To provide the 35 kW of power that the 10 ion engines require, the transfer vehicle uses two high-efficiency solar arrays. The vehicle also has batteries that will provide power while the vehicle is in the shadow of the Earth.

The transfer vehicle weighs approximately 8000 kg. When it is fully loaded with the netting modules, propulsion module, and fuel, the transfer vehicle weighs 30,000 kg. Once the netting vehicle has captured the debris and returned to the transfer vehicle, the total mass of the transfer vehicle is about 21,000 kg. This reduction in weight is due to the fuel that is spent during the capture of the debris.

Control of the transfer vehicle is provided by control moment gyroscopes. The gyros will perform the fine attitude adjustments required as the vehicle makes its rendezvous with the debris. For large maneuvers and momentum dumping, the vehicle also includes RCS thrusts similar to those used by the space shuttle.

Navigation of the transfer vehicle is done by a combination of onboard calculations and data from the ground. Initially, the transfer vehicle receives data about the location of the debris and its location from external sources. From the data, the vehicle plots an intercept course. The vehicle proceeds along its trajectory and modifies it as new data are received about the location of the vehicle with respect to the debris.

The transfer vehicle receives this data from the command center located on Earth via a Ku-band communications link through the TDRSS satellite. The transfer vehicle relays any commands to the netting vehicle with a V-band communications system.

NETTING VEHICLE

The netting vehicle is responsible for gathering the debris and returning it to the transfer vehicle. The layout of the netting vehicle and the modules is shown in Fig. 2.

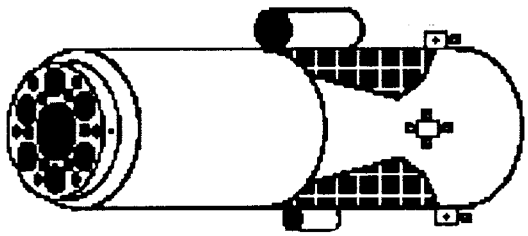

Fig. 2. The layout of the netting vehicle.

Once in the debris orbit, the netting vehicle uses its onboard infrared (IR) tracking system to locate and target a piece of debris. Once the debris is targeted, the netting vehicle does a Hohmann transfer into a slightly different orbit. This allows the netting vehicle to close in on the debris piece. As the vehicle closes in on the debris to a distance of about 25 km, the tracking switches to a LADAR (LAser Detection and Ranging) system. The LADAR system provides more accurate ranging and location information to the netting vehicle as it approaches the debris. When the debris is within about 20 m of the debris, the vehicle will fire a net, capture the debris, and reel the net back into the netting module.

The netting vehicle will be controlled from the ground or elsewhere with teleoperated controls. This will prevent the netting vehicle from having to have extensive artificial intelligence. The communication is relayed to and from the netting vehicle using V-band link from the transfer vehicle through TDRSS. To provide the attitude adjustments, the vehicle will use control moment gyros in conjunction with RCS thrusters. The vehicle will also use hydrazine/nitrous oxide-fueled engines to provide the large orbital changes as the vehicle chases the debris.

Power is provided by solar arrays mounted on the surface of the spacecraft. This arrangement minimizes the surface area of the spacecraft in order to avoid possible collision with debris. The array is also oversized by 25% to compensate for degradation due to debris impacts.

The total mass of the netting vehicle after it leaves the transfer vehicle is 8076.5 kg. Upon gathering all the debris and returning to the transfer vehicle, the mass is reduced to 5183 kg, reflecting fuel expended.