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Inspector and the ISSA

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Abstract

Inspection, maintenance, and repair will be an important part of International Space Station Alpha (ISSA) operations. The ISSA will employ manipulator arms and crew EVA (extra vehicular activity) to perform these functions. Particularly advantageous for safe and effective operations is the capability to visually inspect unpressurized areas of ISSA and to illuminate and monitor EVA tasks.

DASA (Daimler-Benz Aerospace) is developing a free-flying satellite named "Inspector" that, as it evolves, will complement both EVA and manipulator task performance and eventually provide these types of operations. Rockwell Aerospace is working with DASA to design, develop, verify, and operate Inspector.

This paper describes the Inspector spacecraft, its command and control system, the scheduled and proposed flight demonstrations, and its application to ISSA.

Introduction

During buildup, and over the lifetime of the ISSA, there will be numerous occasions when external inspection, maintenance, and repair operations will be required. For ISSA, these operations

will be accomplished with EVA and the ISSA manipulator arms.

However, EVA is a time consuming activity (with elements of risk) and the ISSA manipulator arms will not provide total accessibility to all areas of the ISSA. A free-flying satellite -- properly equipped -- could perform, or at least complement, many of the EVA and manipulator arm operations.

DASA's free-flying satellite, called "Inspector" is being designed to ultimately perform just these types of operations. The initial (prototype) design will feature a video camera that will provide continuous viewing of the outside of the orbiting element as the Inspector is flown around it. The Inspector flight path around the orbiting element will be controlled by an astronaut based either within the orbiting element itself or in another nearby orbiting element. This viewing capability will be very useful in determining the health of an orbiting vehicle and is particularly applicable to ISSA operations. As the Inspector design evolves, capabilities will be added to provide for maintenance and repair functions as well.

Plans are underway to demonstrate the Inspector concept on a Mir-Inspector mission as early as October 1996. Further, a mission is being evaluated in which the Shuttle would fly and retrieve

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the Inspector at the end of the Mir-Inspector mission. Because of this Mir-Inspector-Shuttle combination, DASA (Germany), NPO-Energia (Russia), and Rockwell International (USA) have agreed on a stepwise development of this free-flying automated/robotized servicing system.

The following sections will describe the Inspector system; provide a summary of the Mir-Inspector, Shuttle-Inspector, and ISSA-Inspector missions; and discuss future developments and applications of the Inspector.

Inspector System Description

The Inspector system consists of (1) the Inspector spacecraft -- which carries the video camera and performs the maneuvers required for inspection/observation and (2) the Monitoring and Control System (MCS) -- which provides the man-machine interface between the astronaut and the Inspector spacecraft.

Inspector Spacecraft

The prototype Inspector spacecraft (Figure 1) features low-cost, off-the-shelf

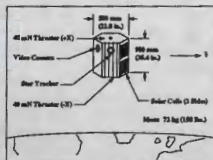


Figure 1 - Inspector Spacecraft

hardware with solar cells on three sides and a video camera and CCD (charge coupled device) star tracker on two of the other sides. The Inspector spacecraft subsystems are:

- Video
- Electrical power
- Guidance, navigation and control
- Data handling
- Telemetry/telecommand
- Propulsion
- Thermal
- Structure

The video subsystem consists of a video (color) camera with a zoom lens fixed to the spacecraft structure. Pointing of the camera at the target is accomplished by orienting the spacecraft to the desired attitude. The video output will be transmitted to the Inspector MCS, via S-band, where it is displayed and recorded.

The electrical power system is a 12 V dc system with a NiCd battery, three solar panels, and a power conditioning and distribution unit (PCDU). There is a connector for external charging for voltage inputs between 23 and 34 V dc.

The guidance, navigation and control subsystem (Figure 2) utilizes the spacecraft star tracker and laser gyros to determine attitude. Attitude control is provided by reaction wheels that can be desaturated by the magnetic torquers. A video navigation system, which uses the video camera image in conjunction with known reference points on the target, provides relative position data. Position control is provided by two thrusters on the spacecraft x-axis (Figure 1) which are oriented in the desired direction by the attitude control system. Orbit and atti-

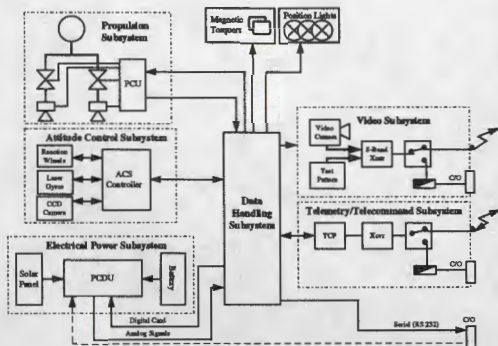


Figure 2 - Inspector Spacecraft Avionics

tude control maneuvers are calculated in the MCS based on astronaut inputs.

The data handling subsystem uses an 8086-based single board computer to process data on the spacecraft and also between the spacecraft and the MCS.

The telemetry/telecommand subsystem transmits and receives data via 2-meter band RF that is compatible with the Mir. Reconfiguration to S-band would be considered for Shuttle/ISSA-Inspector operations.

The propulsion subsystem is a cold gas (nitrogen) blow-down system initially pressurized to 140 bar ($\approx 2,000$ psi). A pressure regulator/relief valve maintains a pressure of 1.2 bar (≈ 20 psi) at each of the two 40 mN (≈ 0.01 lb) thrusters. The two thrusters are oriented opposite each other along the x (longitudinal) axis

of the spacecraft and a latching valve located at each thruster allows for positive thruster shutdown.

Thermal control is passive and uses MLI (multi-layer insulation) and high emissivity Kapton foil as required.

The Inspector spacecraft structure (Figure 3) is modular in design to facilitate integration, interchangeability, accessibility, maintainability, and pretest capability. The central body carries all the equipment, including the propulsion cold gas system; the sidewall enclosures do not carry any equipment. Bridging brackets below the lower floor carry balance weights to control the center of gravity. An ejection system will be provided by NPO-Energia for the Mir-Inspector mission; for the Shuttle and the ISSA, the Inspector will be deployed and

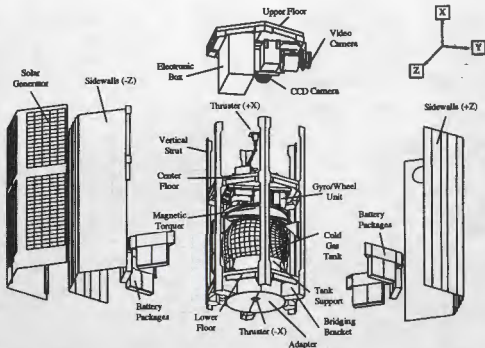


Figure 3 - Inspector Spacecraft Modular Design

retrieved by the RMS (remote manipulator system) and ISSA manipulator, respectively.

Monitoring and Control System (MCS)

The MCS, the man-machine interface with the Inspector spacecraft, provides the following functions:

- Displays/records the video inspection image and essential spacecraft data
- Stores the data and automated mode definitions for guidance, navigation and control
- Processes attitude measurements from the spacecraft sensors and state vector data from the Shuttle and the ISSA
- Generates and issues attitude and orbit control commands for the spacecraft
- Manages electronic signal traffic and switching, both automatic and upon command
- Performs automated, functional checkout of the entire spacecraft system upon command
- Interconnects with the spacecraft for functional checkout and charging of the spacecraft batteries prior to spacecraft deployment.

The MCS for the Mir-Inspector mission is located in the Mir and configured as shown in Figure 4 with DASA furnished components.

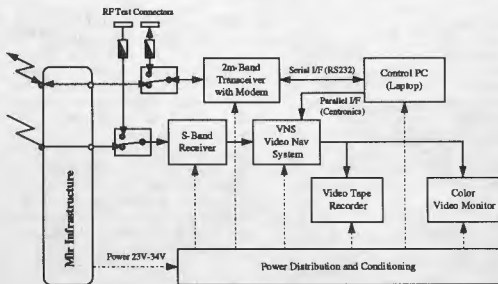


Figure 4 - Mir-Inspector MCS

A proposed Shuttle-based MCS for a Shuttle-Inspector mission, which basically uses existing Shuttle hardware, is shown in Figure 5. This system design,

with some modifications, can also be applied to the ISSA.

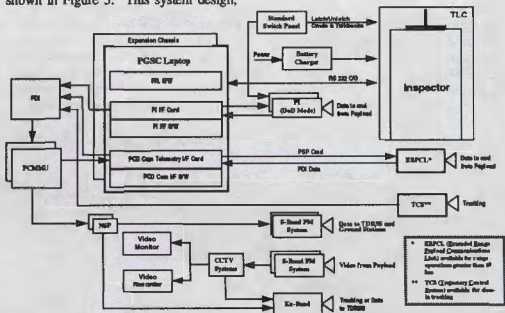


Figure 5 - Shuttle-Inspector MCS

Inspector Missions

The early Inspector missions will be designed to demonstrate the Inspector concept with the prototype spacecraft. A Mir-Inspector mission is now being planned and a Shuttle-Inspector mission is in the proposal stage. Building on these demonstration missions, an increased-capability flight article could be flown operationally with both the Shuttle and the ISSA.

Mir-Inspector Mission

For the Mir-Inspector mission, the Inspector spacecraft will be carried as cargo in the Progress-M aboard the Soyuz launch vehicle. After Progress-Mir docking, the Progress will separate from the Mir and release the Inspector spacecraft. The Inspector then will be flown around the Progress while being controlled from the Mir MCS. Following this first demo flight, the Progress will be placed in a safe disposal trajectory. The Inspector will then be flown around the Mir, again while being controlled from the Mir MCS.

During these fly-arounds, the Inspector video camera will be pointed at the Progress and Mir. The MCS operator will be able to select, suspend, and continue individual maneuvers, observe the images taken, and monitor the status of the spacecraft. The general pattern of the planned Inspector trajectories around the Progress and the Mir is shown in Figure 6. These activities, successfully performed, will demonstrate the usefulness of Inspector as a servicing element for orbiting vehicles. After this demonstration flight, the Inspector will be placed in a safe disposal trajectory.

Shuttle-Inspector Mission

One option under consideration is the utilization of the Shuttle in combination with the Mir-Inspector mission. As noted above, the Mir-Inspector mission ends with the disposal of the Inspector because there are no provisions on Mir to retrieve it. If a Shuttle mission to Mir can be coordinated with the Inspector demo, the Shuttle could retrieve the Inspector with its RMS. Further, if the Shuttle is configured with the Inspector MCS, then the Inspector could be flown

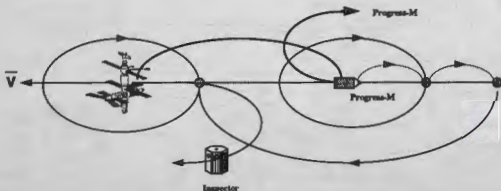


Figure 6 - Mir-Inspector Mission Trajectories

in the vicinity of the Shuttle from its aft flight deck.

The Shuttle-Inspector prototype mission would, therefore, not only retrieve the Inspector for future missions, it would also be an initial step in integrating the Inspector with the Shuttle/ISSA program. As the Inspector evolves, the Shuttle would provide a test bed for the verification of the Inspector flight article.

ISSA-Inspector Mission

The Inspector concept is directly applicable to ISSA operations. Once the flight article is verified, preferably by on-orbit testing in conjunction with the Shuttle, ISSA-Inspector missions will use all the capabilities of the Inspector relative to inspection, maintenance, and repair.

A proposed schedule for Inspector prototype and flight article demonstrations and operations is shown in Figure 7.

Future Development and Applications

The overall objective of the Inspector prototype missions is to determine what design changes are required to produce a flight article that will meet the servicing needs of orbiting elements -- with the ISSA being a prime candidate. The early Inspector prototype missions will support the development of vehicle control and maneuver strategies, and they will also help to refine the man-machine interface requirements.

Key design features that will characterize the Inspector flight article will include stationkeeping capability (relative to the orbiting element it is servicing) and robotic arms (for maintenance and repair). The Inspector spacecraft failure tolerance will be compatible with manned space operations requirements.

The Inspector concept is most certainly going to play a role in future space programs. The Inspector system described here is leading the way.

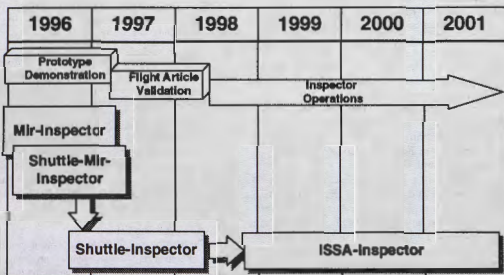


Figure 7 - Inspector Missions