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Automated Rendezvous and Docking: 1994-2004

This custom bibliography from the NASA Scientific and Technical Information Program lists a sampling of records found in the NASA Aeronautics and Space Database. The scope of this topic includes technologies for human exploration and robotic sample return missions. This area of focus is one of the enabling technologies as defined by NASA's *Report of the President's Commission on Implementation of United States Space Exploration Policy*, published in June 2004.

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Automated Rendezvous and Docking: 1994-2004

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October 2004

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OCTOBER 2004

20040086504 NASA Langley Research Center, Hampton, VA, USA

Communications and Tracking of Visiting Vehicles near ISS: The Design of the Reusable Launch Vehicle Communications

Stillwagen, Frederic H.; April 29, 1999; In English; No Copyright; Avail: CASI; A02, Hardcopy

The International Space Station (ISS) will provide for the visitation of various vehicles such as the Shuttle, Automated Transfer Vehicle (ATV), H-II Transfer Vehicle (HTV), Crew Return Vehicle (CRV), Reusable Launch Vehicle (RLV) and Soyuz. These vehicles will provide for crew replacement, consumables resupply, and equipment delivery. In order for these vehicles to approach and eventually dock with the ISS, there must be near continuous communications coverage between the visiting vehicle and the ISS, as well as communications between the vehicle and a Mission Control Center (MCC). Since the ISS communications systems are already designed and scheduled for ISS activation, the vehicles must either utilize these communications systems or provide their own. There are two means of two-way communications with the ISS. These are (1) S-Band communications using TDRSS, and (2) UHF communications using some form of the Space to Space Station Radio (SSSR) link. The RLV utilizes ISS compatible communications systems to communicate with both the ISS and a Mission Control Center. Since all vehicles must adhere to the Visiting Vehicle Interface requirements given in reference 1, the RLV communications system design must meet these requirements during entry into the ISS Approach Ellipsoid (AE) and during Proximity Operations. Included in this paper are descriptions of these communications approaches as well as their potential utilization in the ISS communications system.

Author

Automated Transfer Vehicle; Radio Communication; Reusable Launch Vehicles; Systems Engineering; Telecommunication

20040075053 Michigan Univ., Ann Arbor, MI

Electronically Integrated Active Compliant Transmission (ACT) Actuation Technologies Proof-of-Concept Investigation of Active Velcro for Smart Attachment Mechanisms

Brei, Diann; Lindner, Douglas; Frecker, Mary; LaVigna, Chris; Clement, Joe; Dec. 2003; In English; Original contains color illustrations

Contract(s)/Grant(s): DAAD19-00-1-0441

Report No.(s): AD-A422431; F003271; ARO-41377.1-EG; No Copyright; Avail: CASI; A05, Hardcopy

This report provides a summary of the motivation, methodology and research results for two different projects supported under this effort. In Electrically integrated active compliant transmission (ACT) Actuation Technologies two different actuation approaches were developed, modeled, fabricated and experimentally validated: 1) a d31-approach based on the Recurve architecture that generates higher forces and 2) a d33-approach based upon a compliant mechanism that provides more amplified strain. A first-generation power amplifier was designed that efficiently swaps energy allowing low voltage batteries to produce high voltage drive signals. Both piezoceramic actuation systems were integrated into the INertially STAbilized Rifle (INSTAR) to eliminate aiming errors by stabilizing the barrel assembly providing a significant advancement in small arms. In the second project, Proof-of-Concept Investigation of Active Velcro Autonomous Docking of Micro- and Nano-Satellites, a new connection methodology, Smart Attachment Mechanism (SAM) technology, was invented, modeled and experimentally characterized that possesses the ability to actively connect two surfaces (engagement, retention, release) and effect relative planar motion between them (translation, rotation). This work laid the necessary foundation for further development of this unique paradigm which is useful for any unstable environment (space, fluidic, moving, vibration, etc) where active connection and motion is simultaneously required.

DTIC

Elastic Properties; Fasteners; Proving; Systems Integration

20040071015 Advanced Optical Systems, Inc., Huntsville, AL, USA

Advanced Video Guidance Sensor and Next Generation Autonomous Docking Sensors

Granade, Stephen R.; 2004; In English, 12-16 Apr. 2004, Orlando, FL, USA

Contract(s)/Grant(s): NNM04AA23C; No Copyright; Avail: CASI; A03, Hardcopy

In recent decades, NASA's interest in spacecraft rendezvous and proximity operations has grown. Additional instrumentation is needed to improve manned docking operations' safety, as well as to enable telerobotic operation of spacecraft or completely autonomous rendezvous and docking. To address this need, Advanced Optical Systems, Inc., Orbital Sciences Corporation, and Marshall Space Flight Center have developed the Advanced Video Guidance Sensor (AVGS) under the auspices of the Demonstration of Autonomous Rendezvous Technology (DART) program. Given a cooperative target comprising several retro-reflectors, AVGS provides six-degree-of-freedom information at ranges of up to 300 meters for the DART target. It does so by imaging the target, then performing pattern recognition on the resulting image. Longer range operation is possible through different target geometries. Now that AVGS is being readied for its test flight in 2004, the question is: what next? Modifications can be made to AVGS, including different pattern recognition algorithms and changes to the retro-reflector targets, to make it more robust and accurate. AVGS could be coupled with other space-qualified sensors, such as a laser range-and-bearing finder, that would operate at longer ranges. Different target configurations, including the use of active targets, could result in significant miniaturization over the current AVGS package. We will discuss these and other possibilities for a next-generation docking sensor or sensor suite that involve AVGS.

Author

Autonomy; Guidance Sensors; Imaging Techniques; Miniaturization; Reflectors; Telerobotics

20040071011 NASA Marshall Space Flight Center, Huntsville, AL, USA

Automated Rendezvous and Capture System Development and Simulation for NASA

Roe, Fred D.; Howard, Richard T.; Murphy, Leslie; 2004; In English, 12-16 Apr. 2004, Orlando, FL, USA; No Copyright; Avail: CASI; A02, Hardcopy

The USA does not have an Automated Rendezvous and Capture Docking (AR&C) capability and is reliant on manned control for rendezvous and docking of orbiting spacecraft. T h i s reliance on the labor intensive manned interface for control of rendezvous and docking vehicles has a significant impact on the cost of the operation of the International Space Station (ISS) and precludes the use of any U.S. expendable launch capabilities for Space Station resupply. The Marshall Space Flight Center (MSFC) has conducted pioneering research in the development of an automated rendezvous and capture (or docking) (AR&C) system for U.S. space vehicles. This A M C system was tested extensively using hardware-in-the-loop simulations in the Flight Robotics Laboratory, and a rendezvous sensor, the Video Guidance Sensor was developed and successfully flown on the Space Shuttle on flights STS-87 and STS-95, proving the concept of a video- based sensor. Further developments in sensor technology and vehicle and target configuration have lead to continued improvements and changes in AR&C system development and simulation. A new Advanced Video Guidance Sensor (AVGS) with target will be utilized as the primary navigation sensor on the Demonstration of Autonomous Rendezvous Technologies (DART) flight experiment in 2004. Realtime closed-loop simulations will be performed to validate the improved AR&C systems prior to flight.

Author

Autonomy; Navigation Instruments; Orbital Rendezvous; Rendezvous Guidance; Robotics; Spacecraft Docking

20040071003 NASA Marshall Space Flight Center, Huntsville, AL, USA

Advanced Video Guidance Sensor (AVGS) Development Testing

Howard, Richard T.; Johnston, Albert S.; Bryan, Thomas C.; Book, Michael L.; 2004; In English, 12-16 Apr. 2004, Orlando, FL, USA; No Copyright; Avail: CASI; A03, Hardcopy

NASA's Marshall Space Flight Center was the driving force behind the development of the Advanced Video Guidance Sensor, an active sensor system that provides near-range sensor data as part of an automatic rendezvous and docking system. The sensor determines the relative positions and attitudes between the active sensor and the passive target at ranges up to 300 meters. The AVGS uses laser diodes to illuminate retro-reflectors in the target, a solid-state camera to detect the return from the target, and image capture electronics and a digital signal processor to convert the video information into the relative positions and attitudes. The AVGS will fly as part of the Demonstration of Autonomous Rendezvous Technologies (DART) in October, 2004. This development effort has required a great deal of testing of various sorts at every phase of development. Some of the test efforts included optical characterization of performance with the intended target, thermal vacuum testing, performance tests in long range vacuum facilities, EMI/EMC tests, and performance testing in dynamic situations. The sensor has been shown to track a target at ranges of up to 300 meters, both in vacuum and ambient conditions, to survive and operate

during the thermal vacuum cycling specific to the DART mission, to handle EM1 well, and to perform well in dynamic situations.
Author
Guidance Sensors; Rendezvous Guidance; Digital Systems; Cameras; Thermal Cycling Tests; Signal Processing

20040068088 American Inst. of Aeronautics and Astronautics, Reston, VA, USA
Will the ATV Deliver?
Iannotta, Ben; Aerospace America; July 2003; ISSN 0740-722X; In English; Copyright; Avail: Other Sources

he European Space Agency's work on a fleet of expendable cargo spacecraft for the International Space Station (ISS) has long been viewed as a form of payment-in-kind by European space leaders for the right to attach their Columbus laboratory to the station starting in October 2004. With the grounding of the U S space shuttle fleet, timely development of the Automated Transfer Vehicle (ATV) has acquired new importance for the partners of the ISS.The ATV is the most technically challenging spacecraft Europe has ever designed, because of its automated navigation capabilities and multiple duties. Each ATV will dock automatically at the station s Russian-built Zvezda service module and will remain there for up to six months.
Derived from text
Automated Transfer Vehicle; Planning

20040068076 Orbital Sciences Corp., Dulles, VA, USA
Video-Guidance Design for the DART Rendezvous Mission
Ruth, Michael; Tracy, Chisholm; [2004]; In English, 12-16 Apr. 2004, Orlando, FL, USA
Contract(s)/Grant(s): NAS8-01102; No Copyright; Avail: CASI; A03, Hardcopy

NASA's Demonstration of Autonomous Rendezvous Technology (DART) mission will validate a number of different guidance technologies, including state-differenced GPS transfers and close-approach video guidance. The video guidance for DART will employ NASA/Marshall s Advanced Video Guidance Sensor (AVGS). This paper focuses on the terminal phase of the DART mission that includes close-approach maneuvers under AVGS guidance. The closed-loop video guidance design for DART is driven by a number of competing requirements, including a need for maximizing tracking bandwidths while coping with measurement noise and the need to minimize RCS firings. A range of different strategies for attitude control and docking guidance have been considered for the DART mission, and design decisions are driven by a goal of minimizing both the design complexity and the effects of video guidance lags. The DART design employs an indirect docking approach, in which the guidance position targets are defined using relative attitude information. Flight simulation results have proven the effectiveness of the video guidance design.
Author
Guidance Sensors; Global Positioning System; Flight Simulation; Feedback Control; Attitude Control; Bandwidth

20040068065 NASA Marshall Space Flight Center, Huntsville, AL, USA
Advanced Video Guidance Sensor Development Testing
Howard, Richard T.; Bryan, Thomas C.; Book, Michael L.; Johnston, Albert S.; [2004]; In English, 12-16 Apr. 2004, Orlando, FL, USA; No Copyright; Avail: Other Sources; Abstract Only

NASA's Marshall Space Flight Center was the driving force behind the development of the Advanced Video Guidance Sensor, an active sensor system that provides near-range sensor data as part of an automatic rendezvous and docking system. The sensor determines the relative positions and attitudes between the active sensor and the passive target at ranges up to 300 meters. The VGS uses laser diodes to illuminate retro-reflectors in the target, a solid-state camera to detect the return from the target, and image capture electronics and a digital signal processor to convert the video information into the relative positions and attitudes. This development effort has required a great deal of testing of various sorts at every phase of development, and some of the test efforts, predictions, and results will be laid out in this paper.
Author
Guidance Sensors; Video Communication; Autonomy; Systems Engineering

20040015110 NASA Marshall Space Flight Center, Huntsville, AL, USA

Video Guidance Sensor System with Laser Rangefinder

Howard, Richard T., Inventor; Johnston, Albert S., Inventor; Book, Michael L., Inventor; Bryan, Thomas C., Inventor; December 02, 2003; In English

Patent Info.: Filed 2 May 2002; US-Patent-6,658,329; US-Patent-Appl-SN-138887; NASA-Case-MFS-31399-1; No Copyright; Avail: CASI; A02, Hardcopy

A video guidance sensor system for use in automated docking of a chase vehicle with a target vehicle wherein the chase. vehicle includes a laser rangefinder that uses pulse or phase time of flight measurement to measure distance. The laser rangefinder includes a diode laser pulse or phase driver that produces an output signal to a timing element and simultaneously operates a laser diode. The laser diode produces an intense light beam of a predetermined wavelength which is directed to retroreflectors that are positioned on a passive target. The laser rangefinder includes an avalanche photodetector that produces a corresponding output signal when detecting light reflected from the retroreflectors. The timing element measures a time interval between the output of the laser diode and the detection of light and supplies a corresponding output signal to a computer in order to determine the range of the target vehicle relative to the chase vehicle.

Official Gazette of the U.S. Patent and Trademark Office

Guidance Sensors; Laser Range Finders; Automatic Control; Video Signals

20040013024 Air Force Inst. of Tech., Wright-Patterson AFB, OH, USA

Orbit Determination for a Microsatellite Rendezvous with a Non-Cooperative Target

Foster, Brian L.; Mar. 2003; In English

Report No.(s): AD-A412751; AFIT/GAI/ENY/03-2; No Copyright; Avail: CASI; A07, Hardcopy

This study investigated the minimum requirements to establish a satellite tracking system architecture for a hostile 'parasitic microsatellite' to rendezvous with a larger, non-cooperative target satellite. Four types of tracking systems and their capabilities were reviewed with emphasis on 'low-technology' level and/or mobile systems which could be used by technologically unsophisticated state or non-state adversaries. With the tracking system architecture selected, simulated tracking data was processed with a non- linear least squares orbit determination filter to determine and/or update the target satellite's state vector.

DTIC

Microsatellites; Orbit Determination; Satellite Tracking; Targets; Rendezvous Guidance

20030109067 Army Engineer Research and Development Center, Vicksburg, MS, USA

Design by Analysis of Innovative Navigation Structures: User Manual

Slattery, Kerry T.; Riveros, Guillermo A.; Aug. 2003; In English

Report No.(s): AD-A417396; ERDC/ITL-TR-03-5; No Copyright; Avail: CASI; A07, Hardcopy

This report is the user manual for the 'Design by Analysis System-Innovative Navigation Structures' (DBAS-INS). The Windows-based computer program creates a solid, three- dimensional (3D) finite element model of innovative structures fabricated using 'in-the-wet' construction methods, such as the Braddock Dam currently under construction in the U.S. Army Corps of Engineers' Pittsburgh District. These structures are initially fabricated as a floating shell in a dry dock. The floating shell is divided into a 2D grid of hollow cells separated by reinforced concrete walls. Most significant structural loads involve hydrostatic pressures on the walls as the segment is floated to the installation site, lowered to the foundation, and filled with tremie concrete. The individual concrete slabs that form the walls of the cells must be designed for shear, moment, and thrust loads caused by the expected load combinations on the structure. DBAS-INS procedures were developed to assist in the design and analysis of innovative navigation structures by simplifying the steps required to describe a new design, create a finite element model, check all load cases, design the reinforced concrete structure, and study modifications to the design. The DBAS-INS program allows the designer to create an accurate finite element model for a complex, 3D structure and to complete a preliminary layout and design in a fraction of the time normally required. After analysis, the program checks design requirements per ACI 318-02 (American Concrete Institute 'Building Code Requirements for Structural Concrete') and, based on these results, can automatically modify the design and reanalyze the model.

DTIC

Computer Programs; Computer Aided Design

20030099657 Alcon, Inc., USA, Autonomous Technologies, USA

The Right Track for Vision Correction

SPINOFF 2003: 100 Years of Powered Flight; 2003; In English; Original contains color illustrations; No Copyright; Avail: CASI; A01, Hardcopy

More and more people are putting away their eyeglasses and contact lenses as a result of laser vision correction surgery. LASIK, the most widely performed version of this surgical procedure, improves vision by reshaping the cornea, the clear front surface of the eye, using an excimer laser. One excimer laser system, Alcon s LADARVision 4000, utilizes a laser radar (LADAR) eye tracking device that gives it unmatched precision. During LASIK surgery, laser During LASIK surgery, laser pulses must be accurately placed to reshape the cornea. A challenge to this procedure is the patient s constant eye movement. A person s eyes make small, involuntary movements known as saccadic movements about 100 times per second. Since the saccadic movements will not stop during LASIK surgery, most excimer laser systems use an eye tracking device that measures the movements and guides the placement of the laser beam. LADARVision s eye tracking device stems from the LADAR technology originally developed through several Small Business Innovation Research (SBIR) contracts with NASA s Johnson Space Center and the U.S. Department of Defense s Ballistic Missile Defense Office (BMDO). In the 1980s, Johnson awarded Autonomous Technologies Corporation a Phase I SBIR contract to develop technology for autonomous rendezvous and docking of space vehicles to service satellites. During Phase II of the Johnson SBIR contract, Autonomous Technologies developed a prototype range and velocity imaging LADAR to demonstrate technology that could be used for this purpose. Derived from text

Excimer Lasers; Surgery; Cornea; Laser Applications; Technology Transfer

20030065227 Air Force Inst. of Tech., Wright-Patterson AFB, OH, USA

A Study of Control Laws for Microsatellite Rendezvous with a Noncooperative Target

Tschirhart, Troy A.; March 2003; In English

Report No.(s): AD-A413016; AFIT/GAI/ENY/03-3; No Copyright; Avail: CASI; A05, Hardcopy

This study investigated the feasibility of using a microsatellite to accomplish an orbital rendezvous with a noncooperative target, with a focus on the control laws necessary for achieving such a rendezvous. The relative motions of the microsatellite and the target satellite are described using Hill's equations. The results of an investigation of two different controller methodologies show that an impulsive thrust controller based on the Clohessey-Wiltshire solution used little fuel, but was not very robust. A continuous thrust controller using a Linear Quadratic Regulator was found to be more robust, but used much more fuel. As a final solution, a hybrid controller was evaluated which uses the low thrust Clohessey-Wiltshire approach to cover most of the necessary distance, and then switches to the Linear Quadratic Regulator method for the final rendezvous solution. Results show that this approach achieves rendezvous with a reasonable amount of control input. (23 tables, 29 figures,

DTIC

Orbital Rendezvous; Microsatellites; Control Theory; Target Acquisition; Rendezvous Guidance

20030062183 Orbital Sciences Corp., Dulles, VA, USA

Demonstration of Autonomous Rendezvous Technology (DART) Project Summary

Rumford, TImothy E.; April 24, 2003; In English, 24 apr. 2003, Orlando, FL, USA; No Copyright; Avail: CASI; A02, Hardcopy

Since the 1960's, NASA has performed numerous rendezvous and docking missions. The common element of all US rendezvous and docking is that the spacecraft has always been piloted by astronauts. Only the Russian Space Program has developed and demonstrated an autonomous capability. The Demonstration of Autonomous Rendezvous Technology (DART) project currently funded under NASA's Space Launch Initiative (SLI) Cycle I, provides a key step in establishing an autonomous rendezvous capability for the USA. DART's objective is to demonstrate, in space, the hardware and software necessary for autonomous rendezvous. Orbital Sciences Corporation intends to integrate an Advanced Video Guidance Sensor and Autonomous Rendezvous and Proximity Operations algorithms into a Pegasus upper stage in order to demonstrate the capability to autonomously rendezvous with a target currently in orbit. The DART mission will occur in April 2004. The launch site will be Vandenburg AFB and the launch vehicle will be a Pegasus XL equipped with a Hydrazine Auxiliary Propulsion System 4th stage. All mission objectives will be completed within a 24 hour period. The paper provides a summary of mission objectives, mission overview and a discussion on the design features of the chase and target vehicles.

Author

Spacecraft Docking; Orbital Rendezvous; Unmanned Spacecraft; Guidance Sensors; Optical Measuring Instruments; Design Analysis; Autonomous Navigation

20030061154 NASA Marshall Space Flight Center, Huntsville, AL, USA

The Successful Development of an Automated Rendezvous and Capture (AR&C) System for the National Aeronautics and Space Administration

Roe, Fred D.; Howard, Richard T.; [2003]; In English, 2-6 Feb. 2003, Albuquerque, NM, USA; No Copyright; Avail: CASI; A01, Hardcopy

During the 1990's, the Marshall Space Flight Center (MSFC) conducted pioneering research in the development of an automated rendezvous and capture/docking (AR&C) system for U.S. space vehicles. Development and demonstration of a rendezvous sensor was identified early in the AR&C Program as the critical enabling technology that allows automated proximity operations and docking. A first generation rendezvous sensor, the Video Guidance Sensor (VGS), was developed and successfully flown on STS-87 and STS-95, proving the concept of a video- based sensor. A ground demonstration of the entire system and software was successfully tested. Advances in both video and signal processing technologies and the lessons learned from the two successful flight experiments provided a baseline for the development, by the MSFC, of a new generation of video based rendezvous sensor. The Advanced Video Guidance Sensor (AGS) has greatly increased performance and additional capability for longer-range operation with a new target designed as a direct replacement for existing ISS hemispherical reflectors.

Author

NASA Programs; Space Transportation System; Spacecraft Guidance; Spacecraft Control; Automatic Control

20030057982 Naval Postgraduate School, Monterey, CA

Development and Control of Robotic Arms for the Naval Postgraduate School Planar Autonomous Docking Simulator (NPADS)

Cave, Gary L.; Dec. 2002; In English; Original contains color illustrations

Report No.(s): AD-A411173; No Copyright; Avail: CASI; A06, Hardcopy

This thesis encompasses the development of two robotic arms for integration onto the Naval Postgraduate School (NPS) Planar Autonomous Docking Simulator (NPADS) servicing vehicle, This research effort involved support structure design, fabrication, and construction, off-the-shelf motion control hardware integration, and control algorithm development and testing. The NPADS system is being built as a test platform for spacecraft docking and capture mechanisms designed for autonomous rendezvous and servicing missions. As with the servicing vehicle, the robotic arms utilize a floatation system on an air-bearing granite table to provide a two-dimensional, drag-free environment. DC brushless servo motors serve as shoulder, elbow, and wrist joints allowing planar motion of the two-link arms. A National Instruments (NI) PXI computer and Motion Control card provide system processing and the software to hardware interface. The NI LabVIEW software suite enabled development of manual control code and autonomous control subroutines compatible with the control software of the NPADS main body. A single, wrist-mounted CCD bullet camera provides visual target acquisition for the robotic arms control system. Testing and analysis were completed in the NPS Satellite Servicing Laboratory on a table-based test harness to facilitate initial design iteration.

DTIC

Test Vehicles; Spacecraft Docking; Flight Simulators; Control Simulation

20030038867 Sandia National Labs., Albuquerque, NM

Self-Reconfigurable Robots

Hensinger, D. M.; Johnston, G. A.; Hinman-Sweeney, E. M.; Feddema, J.; Eskridge, S.; Oct. 2002; In English

Report No.(s): DE2002-805834; No Copyright; Avail: National Technical Information Service (NTIS)

A distributed reconfigurable micro-robotic system is a collection of unlimited numbers of distributed small, homogeneous robots designed to autonomously organize and reorganize in order to achieve mission-specified geometric shapes and functions. This project investigated the design, control, and planning issues for self-configuring and selforganizing robots. In the 2D space a system consisting of two robots was prototyped and successfully displayed automatic docking/undocking to operate dependently or independently. Additional modules were constructed to display the usefulness of a selfconfiguring system in various situations. In 3D a self-reconfiguring robot system of 4 identical modules was built. Each module connects to its neighbors using rotating actuators. An individual component can move in three dimensions on its neighbors. We have also built a self-reconfiguring robot system consisting of 9-module Crystalline Robot. Each module in this robot is actuated by expansion/contraction. The system is fully distributed, has local communication (to neighbors) capabilities and it has global sensing capabilities.

NTIS

Robots; Robotics; Control

20030006796

The Successful Development of an Automated Rendezvous and Capture (AR&C) System for the National Aeronautics and Space Administration

Roe, Fred D.; Howard, Richard T.; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; SPACE TECHNOLOGY and APPLICATIONS INT.FORUM-STAIF 2003: Conf.on Thermophysics in Microgravity; Commercial/Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA; Copyright

During the 1990's, the Marshall Space Flight Center (MSFC) conducted pioneering research in the development of an automated rendezvous and capture/docking (AR&C) system for U.S. space vehicles. Development and demonstration of a rendezvous sensor was identified early in the AR&C Program as the critical enabling technology that allows automated proximity operations and docking. A first generation rendezvous sensor, the Video Guidance Sensor (VGS), was developed and successfully flown on STS-87 and STS-95, proving the concept of a video- based sensor. A ground demonstration of the entire system and software was successfully tested. Advances in both video and signal processing technologies and the lessons learned from the two successful flight experiments provided a baseline for the development, by the MSFC, of a new generation of video based rendezvous sensor. The Advanced Video Guidance Sensor (AGS) has greatly increased performance and additional capability for longer-range operation with a new target designed as a direct replacement for existing ISS hemispherical reflectors. [copyright] 2003 American Institute of Physics

Author (AIP)

Ground Support Equipment; Ground Support Systems; NASA Programs; Navigation; Orbital Rendezvous; Research Projects; Spacecraft; Spacecraft Docking

20020092445 Naval Postgraduate School, Monterey, CA USA

Development and Control of the Naval Postgraduate School Planar Autonomous Docking Simulator (NPADS)

Porter, Robert D.; Sep. 2002; In English; Original contains color images

Report No.(s): AD-A407235; No Copyright; Avail: CASI; A06, Hardcopy

The objective of this thesis was to design, construct and develop the initial autonomous control algorithm for the NPS Planar Autonomous Docking Simulator (NPADS) The effort included hardware design, fabrication, installation and integration; mass property determination; and the development and testing of control laws utilizing MATLAB and Simulink for modeling and LabView for NPADS control, The NPADS vehicle uses air pads and a granite table to simulate a 2-D, drag-free, zero-g space environment, It is a completely self-contained vehicle equipped with eight cold-gas, bang-bang type thrusters and a reaction wheel for motion control, A 'star sensor' CCD camera locates the vehicle on the table while a color CCD docking camera and two robotic arms will locate and dock with a target vehicle, The on-board computer system leverages PXI technology and a single source, simplifying systems integration, The vehicle is powered by two lead-acid batteries for completely autonomous operation, A graphical user interface and wireless Ethernet enable the user to command and monitor the vehicle from a remote command and data acquisition computer. Two control algorithms were developed and allow the user to either control the thrusters and reaction wheel manually or simply specify a desired location and rotation angle,

DTIC

Test Vehicles; Spacecraft Docking; Training Simulators; Control Simulation

20020080262 Integrated Sensors, Inc., Utica, NY USA

Motion Tracking System

Spinoff 1994; 1994; In English; No Copyright; Avail: CASI; E99, Hardcopy; There is no charge for this publication. Shipping and handling charges may apply.

Integrated Sensors, Inc. (ISI), under NASA contract, developed a sensor system for controlling robot vehicles. This technology would enable a robot supply vehicle to automatically dock with Earth-orbiting satellites or the International Space Station. During the docking phase the ISI-developed sensor must sense the satellite's relative motion, then spin so the robot vehicle can adjust its motion to align with the satellite and slowly close until docking is completed. ISI used the sensing/tracking technology as the basis of its OPAD system, which simultaneously tracks an object's movement in six degrees of freedom. Applications include human limb motion analysis, assembly line position analysis and auto crash dummy motion analysis. The NASA technology is also the basis for Motion Analysis Workstation software, a package to simplify the video motion analysis process.

Author

Sensors; Tracking (Position); Control Theory; Robot Sensors; Motion Perception

20020076143 Interactive Pictures Corp., Knoxville, TN USA

Spherical Camera

Spinoff 1997; 1997; In English; Original contains color illustrations; No Copyright; Avail: CASI; E99, Hardcopy; There is no charge for this publication. Shipping and handling charges may apply.

Developed largely through a Small Business Innovation Research contract through Langley Research Center, Interactive Picture Corporation's IPIX technology provides spherical photography, a panoramic 360-degrees. NASA found the technology appropriate for use in guiding space robots, in the space shuttle and space station programs, as well as research in cryogenic wind tunnels and for remote docking of spacecraft. Images of any location are captured in their entirety in a 360-degree immersive digital representation. The viewer can navigate to any desired direction within the image. Several car manufacturers already use IPIX to give viewers a look at their latest line-up of automobiles. Another application is for non-invasive surgeries. By using OmniScope, surgeons can look more closely at various parts of an organ with medical viewing instruments now in use. Potential applications of IPIX technology include viewing of homes for sale, hotel accommodations, museum sites, news events, and sports stadiums.

Author

Bioinstrumentation; Cameras; Images; Photography; Position (Location)

20020060126 NASA Johnson Space Center, Houston, TX USA

Androgynous, Reconfigurable Closed Loop Feedback Controlled Low Impact Docking System With Load Sensing Electromagnetic Capture Ring

Lewis, James L., Inventor; Carroll, Monty B., Inventor; Morales, Ray H., Inventor; Le, Thang D., Inventor; Mar. 12, 2002; In English

Patent Info.: Filed 20 Sep. 1999; US-Patent-6,354,540; US-Patent-Appl-SN-405301; US-Patent-Appl-SN-104843; NASA-MSC-22931-1; No Copyright; Avail: CASI; A03, Hardcopy

The present invention relates to a fully androgynous, reconfigurable closed loop feedback controlled low impact docking system with load sensing electromagnetic capture ring. The docking system of the present invention preferably comprises two Docking- assemblies, each docking assembly comprising a load sensing ring having an outer face, one of more electromagnets, one or more load cells coupled to said load sensing ring. The docking assembly further comprises a plurality of actuator arms coupled to said load sensing ring and capable of dynamically adjusting the orientation of said load sensing ring and a reconfigurable closed loop control system capable of analyzing signals originating from said plurality of load cells and of outputting real time control for each of the actuators. The docking assembly of the present invention incorporates an active load sensing system to automatically dynamically adjust the load sensing ring during capture instead of requiring significant force to push and realign the ring.

Official Gazette of the U.S. Patent and Trademark Office

Spacecraft Docking; Impact Tests; Feedback Control; Electromagnets

20020024753 NASA Marshall Space Flight Center, Huntsville, AL USA

An Advanced Video Sensor for Automated Docking

Howard, Richard T.; Bryan, Thomas C.; Book, Michael L.; Roe, Fred, Technical Monitor; [2001]; In English; 20th Digital Avionics Systems Conference, 14-18 Oct. 2001, Daytona Beach, FL, USA; No Copyright; Avail: Other Sources; Abstract Only

This paper describes the current developments in video-based sensors at the Marshall Space Flight Center. The Advanced Video Guidance Sensor is the latest in a line of video-based sensors designed for use in automated docking systems. The X-33, X-34, X-38, and X-40 are all designed to be unpiloted vehicles; such vehicles will require a sensor system that will provide adequate data for the vehicle to accomplish its mission. One of the primary tasks planned for re-usable launch vehicles is to resupply the space station. In order to approach the space station in a self-guided manner, the vehicle must have a reliable and accurate sensor system to provide relative position and attitude information between the vehicle and the space station. The Advanced Video Guidance Sensor is being designed and built to meet this requirement, as well as requirements for other vehicles docking to a variety of target spacecraft. The Advanced Video Guidance Sensor is being designed to allow range and bearing information to be measured at ranges up to 2 km. The sensor will measure 6-degree-of-freedom information (relative positions and attitudes) from approximately 40 meters all the way in to final contact (approximately 1 meter range). The sensor will have a data output rate of 20 Hz during tracking mode, and will be able to acquire a target within one half of a second. The prototype of the sensor will be near completion at the time of the conference.

Author

Automatic Control; Spacecraft Docking; Reusable Launch Vehicles; Guidance Sensors

20020015694 Maryland Univ., College Park, MD USA

Clarke Station: An Artificial Gravity Space Station at the Earth-Moon L1 Point

Ashmore, Matthew; Barkmeyer, Daniel; Daddino, Laurie; Delorme, Sarah; DePasquale, Dominic; Ellithorpe, Joshua; Garzon, Jessica; Haddon, Jacob; Helms, Emmie; Jarabek, Raquel, et al.; Fourth Annual HEDS-UP Forum; 2001; In English; No Copyright; Avail: CASI; A03, Hardcopy

In order to perform deep space life sciences and artificial gravity research, a 315 metric ton space station has been designed for the L1 libration point between the Earth and the Moon. The station provides research facilities for a total of eight crew in two habitats connected to their center of rotation by 68 m trusses. A third mass is offset for stability. Solar arrays and docking facilities are contained on the axis perpendicular to rotation. A total of 320 sq m of floor space at gravity levels from microgravity to 1.2 g's are available for research and experimentation. Specific research capabilities include radiation measurement and testing, human physiological adaptation measurement, and deep space manned mission simulation.
Author

Aerospace Engineering; Research Facilities; Space Stations; Artificial Gravity; Trusses

20020010903 NASA Marshall Space Flight Center, Huntsville, AL USA

Synchronized Autonomous Docking System

Howard, Richard T., Inventor; Book, Michael L., Inventor; Bryan, Thomas C., Inventor; May 08, 2001; In English
Patent Info.: Filed 10 Dec. 1998; US-Patent-6,227,495; US-Patent-Appl-SN-228033; NASA-Case-MFS-31279-1; No Copyright; Avail: CASI; A01, Hardcopy

A synchronized target subsystem for use in an automated docking system for docking a chase vehicle with a target vehicle wherein the chase vehicle is provided with a video camera for feeding digitized frames to an image processing unit which controls a timing circuit. 'Me timing circuit turns on the video camera to digitize a foreground frame and at the same time turns on a transmitter on the chase vehicle. A power generating antenna on the target vehicle receives the transmitted signal from the transmitter and actuates lights on the chase vehicle so that these lights appear in the foreground frame. After the foreground frame has been grabbed, the timing circuit turns the transmitter off and signals the video camera to digitize a background frame. The image processing unit subtracts the background frame from the foreground frame and provides a docking signal.
Official Gazette of the U.S. Patent and Trademark Office

Autonomy; Image Processing; Spacecraft Docking; Cameras

20020010895 NASA Marshall Space Flight Center, Huntsville, AL USA

Synchronized Docking System

Howard, Richard T., Inventor; Book, Michael L., Inventor; Bryan, Thomas C., Inventor; Jul. 03, 2001; In English
Patent Info.: Filed 10 Dec. 1998; US-Patent-6,254,035; US-Patent-Appl-SN-228071; NASA-Case-MFS-31278-1; No Copyright; Avail: CASI; A01, Hardcopy

A synchronized target subsystem for use in an automated docking system for docking a chase vehicle with a target vehicle wherein the chase vehicle is provided with a video camera for feeding digitized frames to an image processing unit which feeds signals to a control circuit. The control circuit turns on the video camera to digitize a background frame which will include the target vehicle. After the camera grabs the background frame the control circuit turns on a light, which is carried by carried on the chase vehicle and aimed at the target vehicle, and signals the video camera to digitize a foreground frame. A light sensing circuit on the target vehicle receives the light from the chase vehicle and connects a power supply to lights on the target vehicle such that when the foreground frame is digitized the Lights on the target vehicle will show in the foreground frame. Die image processing unit subtracts the background frame from the foreground frame and provides a docking signal.
Official Gazette of the U.S. Patent and Trademark Office

Image Processing; Spacecraft Docking; Detection

20020001038 Lawrence Livermore National Lab., Livermore, CA USA

Six degrees of freedom end effector places 8000 lbs robotic canisters in the National Ignition Facility

McMahon, D.; Tiszauer, D.; Yakuma, S.; Jan. 28, 1999; In English
Report No.(s): DE2001-8513; UCRL-JC-133042; No Copyright; Avail: Department of Energy Information Bridge

The National Ignition Facility (NIF), currently under design and construction at Lawrence Livermore National Laboratory, will be the world's largest laser when complete. The NIF will use about 8000 large optics of 26 different types

to focus up to 192 laser beams on a dime-size target. A system of auto-guided robotic vehicles transports opto-mechanical packages, called line replaceable units (LRUs), for installation and maintenance operations. Most LRUs are transported inside a portable clean room, or canister, containing robotic mechanisms that insert each LRU into its respective location in the laser. Together the LRU and canister can weigh up to 8000 lb. Due to precision-alignment requirements of the LRU and because the canister internal mechanisms operate in the canister reference frame, the canisters themselves must be precisely located relative to the laser support structure. In many instances precise location is obtained with the aid of precision canister locating points, called docking points, some of which are on the laser bay ceiling at 19 feet off the floor. The robotic vehicle transporting the LRU and canister is tasked with positioning these 8000 lb. Canisters at 19-foot elevation with less than one inch offset error. The final positioning of the canister in six degrees of freedom is accomplished with an actively controlled three degree of freedom end effector coupled to a passive three degrees of freedom canister lift system.
NTIS
Degrees of Freedom; Robotics; Clean Rooms; End Effectors

20010071153 NASA Marshall Space Flight Center, Huntsville, AL USA
2nd & 3rd Generation Vehicle Subsystems
Space Transportation Technology Workshop: Propulsion Research and Technology; [2000]; In English; No Copyright; Avail: CASI; A06, Hardcopy

This paper contains viewgraph presentation on the '2nd & 3rd Generation Vehicle Subsystems' project. The objective behind this project is to design, develop and test advanced avionics, power systems, power control and distribution components and subsystems for insertion into a highly reliable and low-cost system for a Reusable Launch Vehicles (RLV). The project is divided into two sections: 3rd Generation Vehicle Subsystems and 2nd Generation Vehicle Subsystems. The following topics are discussed under the first section, 3rd Generation Vehicle Subsystems: supporting the NASA RLV program; high-performance guidance & control adaptation for future RLVs; Evolvable Hardware (EHW) for 3rd generation avionics description; Scaleable, Fault-tolerant Intelligent Network or X(trans)ducers (SFINIX); advance electric actuation devices and subsystem technology; hybrid power sources and regeneration technology for electric actuators; and intelligent internal thermal control. Topics discussed in the 2nd Generation Vehicle Subsystems program include: design, development and test of a robust, low-maintenance avionics with no active cooling requirements and autonomous rendezvous and docking systems; design and development of a low maintenance, high reliability, intelligent power systems (fuel cells and battery); and design of a low cost, low maintenance high horsepower actuation systems (actuators).
CASI
Launch Vehicles; Spacecraft Design; Systems Engineering; Spacecraft Components; Avionics; Component Reliability; Design Analysis; Product Development

20010069677 National Space Development Agency, Hamamatsu, Japan
NASDA Annual Report on Research and Development Fiscal Year 1997
September 2000; ISSN 1345-7926; In English; Also, available with 4 other reports on CD-ROM. See 20010068892.
Report No.(s): NASDA-ETR-000005; NASDA-SPP-990001; Copyright; Avail: CASI; A20, Hardcopy; US Distribution and Sales Only

Over the past year, NASDA has successfully carried out two major experiments with the Engineering Test Satellites VII (ETS-VII) 'Orihime' and 'Hikoboshi', both launched in November 1997. The first experiment was a teleoperated control of robot subsystem; the second was the world's first automatic control rendezvous-and-docking between pilotless spacecraft. Both experiments represent a major technological step towards freer development of space activities in the future. In the area of manned space activity, the astronaut Mukai traveled aboard the U.S. space shuttle 'Discovery' during the year, becoming the first Japanese to go to space for the second time. In November 1998, construction of the international space station began with the launch of the basic function module 'Zarya', the station's first component. This launch marked the beginning of a new stage for international manned space activity. However, there were also setbacks. The second combustion of the second engine during the launch of the H-11 rocket 5 finished earlier than planned, and the 'Kakehashi', Communications and Broadcasting Engineering Test Satellite (COMETS) could not be put into its geostationary transfer orbit. After this engine failure, a series of accidents and complications occurred, including that of the 'Kiku-6', Engineering Test Satellite VI (ETS-VI). In response to these accidents and complications, the Space Activities Commission has been holding a 'Conference on Basic Problems in Space Development.' In addition, institution evaluation and problem evaluation was made based on the general guidelines of the Space Activities Commission. NASDA is currently pursuing system-wide reforms based on these evaluations as well as the Conference's findings. To strengthen the Agency's technology development ability, the Office of Research and Development has been placed at the center of all efforts to develop and establish new technologies. Looking

forward, we plan to propose new system research projects and to drive for perfection at the research planning stage, to ensure that space development activities proceed in a reliable, advanced manner. The present publication is a brief survey of the research activities carried out by NASDA in 1997. We hope that it will deepen the reader's understanding of NASDA's current research agenda, which forms a central part of our commitment to future progress in space.
Author
Japanese Space Program; Aerospace Engineering; Aerospace Systems; Research and Development

20010041293 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
A Highly Miniaturized Inertial Grade Gyroscope for Space Applications
Wiberg, D. V.; Challoner, A. D.; Shcheglov, K.; Hayworth, K.; Bae, S.; Yee, K.; Blaes, B.; DAgostino, S.; Stock, T.; Forum on Innovative Approaches to Outer Planetary Exploration 2001-2020; 2001; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

The evolution of inertial grade gyroscopes for space applications represents well over 50 years of technology development and an investment of hundreds of millions of dollars. The workhorse product which represents the current state-of-the art for commercially available high performance devices is the Litton-Hemishperical Resonator Gyro (HRG) Inertial Measurement Unit (IMU). This product has a performance figure of merit of 0.003 deg/hr bias drift, a volume of 567 cubic inches, weighs 19 pounds, draws about 30 watts and costs over $1 million each. Clearly devices of this magnitude are not conducive to the minimized mass, volume, power, and cost constraints of outer planet missions. An approach to breaking these potential barriers is the use of Microelectromechanical Systems (MEMS) based inertial devices. Although substantially reduced in size, mass power and cost, this approach has produced devices in the tactical performance range of greater than 1 deg/hour bias drift. This level of performance satisfies the preponderance of high market volume requirements such as automotive and tactical munitions but does not meet the limited market quantity requirements for the high precision space based market. Because of the very limited size of the space based market, there is little economic incentive for commercial fabricators of tactical grade devices to address the necessary performance improvements. The Jet Propulsion Laboratory (JPL) in conjunction with Boeing Space Systems (BSS) is addressing this void to satisfy our mutual requirements in this area. The project objective to is to achieve 0.01 deg/hr performance in an IMU which is less than 10 cubic inches in volume, weighs less than 0.5 pounds, draws less than 1 watt and is available in volume production for less than $2500. Reductions of this magnitude will be mission enabling capabilities for a variety of anticipated outer planet mission attributes such as autonomous control and docking, formation flying and robotic outposts. The improved performance will be realized using improved relative precision fabrication, enhanced vibratory drive and sense designs, and statistical data analysis.
Derived from text
Microelectromechanical Systems; Gyroscopes; Miniaturization; Space Missions

20010021603 NASA Marshall Space Flight Center, Huntsville, AL USA
Video-Based Sensor for Robotic Position and Attitude determination
Howard, Richard T.; Bryan, Thomas C.; Book, Michael L.; Roe, Fred D., Jr., Technical Monitor; [2001]; In English; 6th Artificial Intelligence, Robotics, and Automation in Space, 18-22 Jun. 2001, Montreal, Canada; No Copyright; Avail: Other Sources; Abstract Only

NASA's Marshall Space Flight Center (MSFC) has, for the last ten years, developed various video-based sensors for use in automated docking systems. The latest generation of sensor will operate at rates of up to 100 Hz, determining the relative position (X, Y, and Z) and attitude (Roll, Pitch, and Yaw) between the sensor and a small 3-dimensional target, making it suitable for applications in robotic sensing. The Advanced Video Guidance Sensor (AVGS) is designed to track multiple targets at different ranges and determine the position and attitude of each one. The previous generation of video sensor, the Video Guidance Sensor (VGS), was flown twice on the Space Shuttle to test its performance on orbit. One of the tests performed was determining the relative positions and attitudes between the VGS and its target, which was moved to various positions using the Remote Manipulator System (RMS). The RMS position data and VGS measured data were analyzed after the flights, with good correlation between the position and attitude data of the two data sets. The test using the RMS gives a good idea of the ability of the use of the AVGS as a sensor for end-effector position and attitude determination.
Author
Attitude (Inclination); Robotics; Video Equipment; Guidance Sensors; Position (Location)

20010000880 NASA Johnson Space Center, Houston, TX USA
Evaluation of X-38 Crew Return Vehicle Input Control Devices in a Microgravity Environment
Welge, Kirsten; Moore, Alicia; Pope, Ruth Ann; Shivers, Suzette; Fox, Jeffrey; December 2000; In English
Report No.(s): NASA/TM-2000-208925; S-857; NAS 1.15:208925; No Copyright; Avail: CASI; A03, Hardcopy

This report was created by students from Longview High School, Longview, Texas. Longview High School was selected from a group of Texas high schools to participate in the 1999 Texas Fly High Program. This program gives Texas high school students a chance to work with NASA engineers to design and fly a real-world experiment aboard the KC-135 during zero-g parabolas. Jeffrey Fox's role was to provide a concept for the experiment and to mentor the students in its design and testing. The students were responsible for executing all phases of the project. The X-38 Project Office at the Lyndon B. Johnson Space Center Johnson Space is designing a crew return vehicle (CRV) to be docked at the International Space Station for crew rescue in an emergency. Vehicle controls will be almost completely automated, but a few functions will be manually controlled. Four crew input control devices were selected for evaluation by Longview High School students as part of the 1999 Texas Fly High program. These were (1) Logitech Trackman Marble (optical trackball), (2) Smart Cat Touchpad. (3) Microsoft SideWinder 3D-Pro Joystick, and (4) Microsoft SideWinder Gamepad. In two flight tests in the KC-135 aircraft and a series of ground tests, the devices were evaluated for ability to maneuver an on-screen cursor, level of accuracy, ease of handling blind operations, and level of user comfort in microgravity. The tests results led to recommendation of further tests with the Joystick and the Trackman by astronauts and actual space station residents.
Author
X-38 Crew Return Vehicle; Control Equipment; Flight Tests; Ground Tests; Manual Control; Microgravity

20000083930 National Space Development Agency, Hamamatsu, Japan
Outline of the ETS-VII Project
Mitsushige, Oda; Mission of the Engineering Test Satellite No. 7; December 1999; In English
Report No.(s): NASDA-ETR-990003; NASDA-TMR-970002; Copyright; Avail: CASI; A03, Hardcopy; US Distribution and Sales Only

In the future, many space activities including transportation of the supplies to the International Space Stations (ISS) and platforms, inspection and repair of the failed satellites, various experiments on unmanned platforms, exploration on the surfaces of the Moon and other planets and so forth are expected to be carried out. Furthermore, it is expected that automization and robotization will play an important role in reducing and supplementing the workload of the crews of spacecraft. The rendezvous docking (RVD) and space robot technologies are indispensable for realizing the spacecraft's approach and docking with a spacecraft in an orbit and the various missions including inspection and replacement of the equipment on it. ETS-VII is a satellite which has been designed for the orbital engineering test aiming at the acquisition of the fundamentals of RVD and Robot technologies.
Derived from text
Aerospace Engineering; Transportation; Space Stations; Space Transportation; Inspection; Supplying

20000083929 National Space Development Agency, Hamamatsu, Japan
Mission of Project
Mitsushige, Oda; Mission of the Engineering Test Satellite No. 7; December 1999; In English
Report No.(s): NASDA-ETR-990003; NASDA-TMR-970002; Copyright; Avail: CASI; A04, Hardcopy; US Distribution and Sales Only

The mission of ETS-VII includes: (a) Experiments on Rendezvous Docking (RVD) Technology (NASDA); (b) Experiments on the automated rendezvous and docking of unmanned spacecraft (the chaser and target satellites); (c) Remote piloting experiment of the chaser satellite from ground station; and (d) RVD experiments assuming approaches to the International Space Station.
Derived from text
Space Missions; Spacecraft Docking; Ground Stations; Orbital Rendezvous

20000083926 National Space Development Agency, Hamamatsu, Japan
Rendezvous Docking (RVD) Technology, Appendix 1
Mitsushige, Oda; Mission of the Engineering Test Satellite No. 7; December 1999; In English
Report No.(s): NASDA-ETR-990003; NASDA-TMR-970002; Copyright; Avail: CASI; A03, Hardcopy; US Distribution and Sales Only

In future space development, it is necessary to enable the transportation of supplies, inspection and repair of artificial satellites in orbits, exploration of the moon and other planets, and so forth. At first, it was planned that only the Space Shuttle would be used for the construction and operation of the International Space Station. However, since the amount of materials which have to be transported into orbit is too huge for the Space Shuttle alone to handle, the membership countries of the

International Space Station project, Russia, EU and Japan, are going to share the task of transporting the materials for the construction and operation of the International Space Station. Russia intends to offer their launch vehicles and spacecraft which they have been using for the construction and operation of their orbital science station 'Mir'. The European Space Agency has been developing a new launch vehicle, Ariane V, which will be launched by the Automated Transfer Vehicle, ATV. NASDA, Japan, has also been developing the H-II Transfer Vehicle, HTV, which will transport supplies into orbit. The Rendezvous Docking technology, which enables a spacecraft to approach another spacecraft in an orbit (target: a space station or an artificial satellite) and dock the target, is indispensable for the realization of HTV, as well as the inspection and repair of an artificial satellite in an orbit, the exploration and recovery of the soil samples of the moon and other planets.
Derived from text
Spacecraft Docking; Automated Transfer Vehicle; Space Shuttles

20000052448 General Accounting Office, Washington, DC USA
Space Station: Russian Compliance With Safety Requirements
Li, Allen; Mar. 16, 2000; In English
Report No.(s): AD-A375270; GAO/T-NSIAD-00-128; No Copyright; Avail: CASI; A02, Hardcopy

This report discusses our ongoing work on the National Aeronautics and Space Administration's (NASA) International Space Station. We are currently responding to a request from the Committee Chairman to review Russian compliance with space station safety requirements. We plan to finalize our work and report on this issue next month. Today, we will address (1) significant areas where the Russian-built Zarya and Service Module do not comply with safety requirements, (2) NASA's review and approval of noncompliances and (3) whether NASA was due any compensation from the Zarya contractor for noncompliance or performance problems. NASA invited Russia to participate in the International Space Station program in 1993 with the expectation that Russian involvement would reduce the cost, speed up the schedule, and increase the usefulness of the space station. The Russian-built Zarya and Service Module are critical to the early stages of the space station's assembly. The Zarya module, launched by Russia in November 1998, provides the initial propulsion and guidance functions for the space station. Zarya was funded by NASA and is therefore considered a U.S. element of the space station. The Service Module, whose launch has been delayed until at least July 2000, will provide living quarters, life support systems, and guidance functions after docking with Zarya. Russia is funding, building, and launching the Service Module as part of its contribution to the space station. Russia also plans to contribute Progress resupply vehicles, Soyuz crew transfer and emergency return vehicles, a power platform, docking and stowage modules, and research modules.
DTIC
International Space Station; Service Modules; Soyuz Spacecraft; Spacecraft Docking; Zarya Control Module; U.S.S.R. Space Program; Spacecraft Docking Modules

20000051488 Department of Energy, Washington, DC USA
Robotic inspection experimental system (ARIES) and BOA
Feb. 28, 1998; In English
Report No.(s): DE98-058273; DOE/MC/32260-4; No Copyright; Avail: Department of Energy Information Bridge

ARIES consists of a 6-wheeled K3A mobile platform, a compact subturret, a sonar imaging system, a laser-based light detection and ranging (lidar) navigation beacon system, and a camera positioning system. It has a sonar imaging system used in navigation and collision avoidance and an automatic docking/charging system. Drum-referencing algorithms and camera-positioning algorithms have been included in the primitive instruction set for the robot. The robot's navigation is based on Synchro-Drive, a patented design that utilizes concentric shafts to distribute drive and steering power to the six wheels simultaneously. ARIES uses a virtual path concept in which only a limited amount of information needs to be provided to the control computer in order to get the vehicle moving. The safety and health evaluation, during the human factors assessment, found several areas of concern including ergonomics, laser hazards, tripping hazards, fall-from-above and struck-by hazards, electrical hazards, and decontamination of the system. BOA is a self-propelled automated mini-enclosure, able to remove insulation from installed pipes, primarily of 4 inch nominal outside diameter. The system is designed for two operators: one oversees the abatement head operation from a distance of 10 or 15 feet using a pendant control and the other bags the debris at a cyclonic bagging station that is attached by a vacuum hose to the cutting head. Since the abatement head is its own enclosure, there may be no need for further enclosures to be built. The system wets and removes asbestos insulation automatically, cutting the debris into consistent chunks and moving the wave under a strong vacuum to a bagging machine. Prior to reaching the bagging operation, the material passes through a water separator which greatly reduces the weight of the debris and allows recirculation of water, after sufficient filtration. The safety and health evaluation, during the human factors assessment, focused on: noise, dust concentrations, ergonomics, and computer software. Industrial hygiene sampling indicated

that worker exposures may be kept low enough during normal operation of BOA to eliminate the need for respiratory or heating protection while working around the cutting head and bagging operation. Airborne particulate measurements showed a slight rise over background levels during the operation of BOA, but the average of all the readings during operation was 1.6% of the OSHA respirable dust standard. Air sampling and noise monitoring showed dust to be negligible. Noise was shown to be a potential exposure hazard depending on worker location.
NTIS
Inspection; Robotics; Human Factors Engineering

20000033369 National Space Development Agency, Hamamatsu, Japan
Study of Rendezvous and Docking Technology: Study of Advanced Rendezvous Technology Study of Improvement of the Effective Guidance Period and Accuracy of a VIC Guidance Law for Rendezvous Orbital Maneuver
Yamanaka, Koji; Yokota, Kiyomi; National Space Development Agency of Japan Annual Report on Research and Development Fiscal Year 1996; December 1998; In English; Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

As a guidance law during rendezvous maneuver of a rendezvous spacecraft such as space station logistic system (HTV: H-11 Transfer Vehicle), etc., a VIC (Velocity Increment Cutoff) guidance law is most promising. The VIC guidance law is the guidance law to calculate an required velocity increment vector to get on the target orbit through an impulse calculation and increase a spacecraft velocity toward the appropriate direction until it attains the right velocity vector to get to the target. It is a very simple guidance law, yet it has successful guidance records in the guidance of the H-II when it restarted the second stage engine and of OREX, an exoatmospheric reentry experiment mission, when it escaped from the orbit. In rendezvous maneuver, however, a long duration time of maneuver may be required because of its nature or by an accidental failure of propulsion system. In fact, the first maneuver of an HTV after the separation of the rocket requires a velocity increment of at least 100 m/s, which corresponds to 320 seconds or more of run-duration, when a propulsion system of 400ON is used for the HTV of 13t in weight after separation. As the VIC guidance is formulated on the basis of an impulse orbital maneuver, errors may occur or, in the worst case, a guidance calculation itself may diverge, if a required run-duration is prolonged. The purpose of this study is to modify the VIC guidance law to improve its effective guidance period and accuracy so that it may become adaptable to rendezvous maneuver of the HTV through analyses of the causes of errors in VIC guidance when a long run-duration is required, There is, of course, an inevitable limitation in the effective guidance period, but this study targeted a guidance period of about 1000 seconds. With respect to improvement of its accuracy, a particular emphasis was placed on the semimajor axis of an orbit, an important factor in a rendezvous.
Author
Orbital Rendezvous; Spacecraft Docking; Rendezvous Guidance; Rendezvous Trajectories; Space Rendezvous; Spacecraft Guidance

20000033268 NASA Marshall Space Flight Center, Huntsville, AL USA
Test Results for the Automated Rendezvous and Capture System
Cruzen, Craig; Dabney, Richard; Lomas, James; November 1999; In English, 2-6 Feb. 2000, Breckenridge, CO, USA; No Copyright; Avail: CASI; A03, Hardcopy

The Automated Rendezvous and Capture (AR&C) system was designed and tested at NASA's Marshall Space Flight Center (MSFC) to demonstrate technologies and mission strategies for automated rendezvous and docking of spacecraft in Earth orbit, The system incorporates some of the latest innovations in Global Positioning, System space navigation, laser sensor technologies and automated mission sequencing algorithms. The system's initial design and integration was completed in 1998 and has undergone testing at MSFC. This paper describes the major components of the AR&C system and presents results from the official system tests performed in MSFC's Flight Robotics Laboratory with digital simulations and hardware in the loop tests. The results show that the AR&C system can safely and reliably perform automated rendezvous and docking missions in the absence of system failures with 100 percent success. When system failures are included, the system uses its automated collision avoidance maneuver logic to recover in a safe manner. The primary objective of the AR&C project is to prove that by designing a safe and robust automated system, mission operations cost can be reduced by decreasing the personnel required for mission design, preflight planning and training required for crewed rendezvous and docking missions.
Author
Space Rendezvous; Spacecraft Docking; Performance Tests; Digital Simulation; Systems Engineering; Automatic Control

20000028374 Marquette Univ., Milwaukee, WI USA

An Investigation of Multipath Effects on the GPS System During Auto-Rendezvous and Capture

Richie, James E.; Forest, Francis W.; Mar. 1995; In English

Contract(s)/Grant(s): NAG8-256

Report No.(s): NASA/CR-95-206093; NAS 1.26:206093; No Copyright; Avail: CASI; A10, Hardcopy

The proposed use of a Cargo Transport Vehicle (CTV) to carry hardware to the Space Station Freedom (SSF) during the construction phase of the SSF project requires remote maneuvering of the CTV. The CTV is not a manned vehicle. Obtaining the relative positions of the CTV and SSF for remote auto-rendezvous and capture (AR&C) scenarios will rely heavily on the Global Positioning System (GPS). The GPS system is expected to guide the CTV up to a distance of 100 to 300 meters from the SSF. At some point within this range, an optical docking system will take over the remote guidance for capture. During any remote guidance by GPS it is possible that significant multipath signals may be caused by large objects in the vicinity of the module being remotely guided. This could alter the position obtained by the GPS system from the actual position. Due to the nature of the GPS signals, it has been estimated that if the difference in distance between the Line of Sight (LOS) path and the multipath is greater than 300 meters, the GPS system is capable of discriminating between the direct signal and the reflected (or multipath) signal. However, if the path difference is less than 300 meters, one must be concerned. This report details the work accomplished by the Electromagnetic Simulations Laboratory at Marquette University over the period December 1993 to May 1995. This work is an investigation of the strength and phase of a multipath signal arriving at the CTV relative to the direct or line of sight (LOS) signal. The signal originates at a GPS satellite in half geo-stationary orbit and takes two paths to the CTV: (1) the direct or LOS path from the GPS satellite to the CTV; and (2) a scattered path from the GPS satellite to the SSF module and then to the CTV. The scattering from a cylinder has been computed using the physical optics approximation for the current. No other approximations or assumptions have been made including no assumptions regarding the far field or Fresnel field approximations. The integrations required to obtain the scattered field have been computed numerically using an N dimensional Romberg integration. The total scattered electric field is then projected onto the RCP component in the direction of propagation only. The direct or line of sight signal is then used to compute the relative strength and phase of the scattered field. The trajectory of the CTV has been parameterized into 4,214 points that are calculated for each of the geometries investigated. The motion of the CTV between points is small enough for the magnitude data (dB down from direct signal) to appear very smooth; however, because of the distances and wavelengths involved, the phase of the scattered field relative to the direct signal varies very rapidly.

Derived from text

Global Positioning System; Research; Navigation Satellites; Spacecraft Docking; Trajectory Optimization; Signal Analysis; Line of Sight; Transport Aircraft

20000012182 Russian Inst. of Radionavigation and Time, Saint Petersburg, Russia

'Soyuz'-'Mir' Orbital Flight GPS/GLONASS Experiment: First Results

Klyushnikov, Sergey; Filatchenkov, Sergey; Mikhailov, Nicolai; Pospelov, Sergey; Vasilyev, Mikhail; 6th Saint Petersburg International Conference on Integrated Navigation Systems; October 1999; In English; Copyright; Avail: CASI; A02, Hardcopy

The combined GPS/GLONASS (Global Positioning System/Global Navigation Satellite System) receiver ASN-2401P has been installed on the manned space ship 'Soyuz-TM28' and was used to obtain experimental data during its flight to the space station 'Mir' in August - November 1998. The ASN-2401P receiver is based on the ASN-22 eighteen-channel C/A-code avionics receiver module: a joint development of Dasa NFS (Germany, Ulm) and RIRT (Russia, St.Petersburg). The ASN-22 receiver module is described in brief. The receiver used in the experiment together with the antenna will become core elements of navigation system of Russian module of International Space Station 'Alpha' and Russian space ships. Raw pseudorange and carrier phase measurements, along with the position, velocity and time (PVT) results have been recorded during the autonomous flight of 'SoyuzTM28', rendezvous operations, as well as during the docked to 'Mir' flight. The receiver installation, space ship attitude orientation modes, receiver control and data recording are described. Analysis of flight data is presented in the paper.

Author

Global Positioning System; Mir Space Station; Soyuz Spacecraft; International Space Station; Space Rendezvous; GLONASS; Flight Tests

20000004828 NASA Marshall Space Flight Center, Huntsville, AL USA

Orbital Fluid Transfer System

Johnston, A. S., (Nick); Ryder, Mel; Tyler, Tony R.; 1998; In English, 28-30 Oct. 1998, Huntsville, AL, USA; No Copyright; Avail: Other Sources; Abstract Only

An automated fluid and power interface system needs to be developed for future space missions which require on orbit consumable replenishment. Current method of fluid transfer require manned vehicles and extravehicular activity. Currently the US does not have an automated capability for consumable transfer on-orbit. This technology would benefit both Space Station and long duration satellites. In order to provide this technology the Automated Fluid Interface System (AFIS) was developed. The AFIS project was an advanced development program aimed at developing a prototype satellite servicer for future space operations. This mechanism could transfer propellants, cryogens, fluids, gasses, electrical power, and communications from a tanker unit to the orbiting satellite. The development of this unit was a cooperative effort between Marshall Space Flight Center in Huntsville, Alabama, and Moog, Inc. in East Aurora, New York. An engineering model was built and underwent substantial development testing at Marshall Space Flight Center (MSFC). While the AFIS is not suitable for spaceflight, testing and evaluation of the AFIS provided significant experience which would be beneficial in building a flight unit. The lessons learned from testing the AFIS provided the foundation for the next generation fluid transfer mechanism, the Orbital Fluid Transfer System (OFTS). The OFTS project was a study contract with MSFC and Moog, Inc. The OFTS was designed for the International Space Station (ISS), but its flexible design could used for long duration satellite missions and other applications. The OFTS was designed to be used after docking. The primary function was to transfer bipropellants and high pressure gases. The other items addressed by this task included propellant storage, hardware integration, safety and control system issues. A new concept for high pressure couplings was also developed. The results of the AFIS testing provided an excellent basis for the OFTS design. The OFTS meet the servicing requirements for ISS and could also provide the automated fluid and power interface system needed for on orbit consumable resupply of spacecraft into the new century.
Author
Orbital Servicing; Transfer Orbits; Fluid Power; Orbit Transfer Vehicles

19990115857 NASA Marshall Space Flight Center, Huntsville, AL USA
On Orbit Testing of the Video Guidance Sensor
Howard, Richard T.; Bryan, T. C.; Book, M. L.; [1999]; In English, 6-9 Apr. 1999, Orlando, FL, USA; No Copyright; Avail: Other Sources; Abstract Only;

The Video Guidance Sensor (VGS), part of NASA's Automated Rendezvous and Capture program, was flown on Shuttle mission STS-95 in October of 1998 to orbitally test the functional characteristics of the VGS. This was the second flight of the VGS (the first flight was in 1997 on STS-87), and this time long-range tracking data was gathered during the experiment. The flight experiment sensor was designed to operate from 1.5 meter range out to 110 meter range, with a field-of-view of 16 X 21 degrees. The VGS tracked its target at a 5 Hz rate and returned 6-degree-of-freedom information on the target's position and attitude relative to the sensor. The VGS was mounted in the Shuttle cargo bay, and its target was mounted on the Spartan spacecraft being carried on this mission. The orbital testing of the VGS included operations with the target on the Shuttle's Remote Manipulator System (RMS) at the start of the 10-day mission, long-range data during the Shuttle rendezvous with the Spartan two days later, and some more RMS operations later in the mission. The data returned from the orbital testing included VGS diagnostics, acquisition, and tracking data, RMS positions, hand-held laser range data, tapes of the data from the VGS video camera, and orbital positioning data from the Spartan and the Shuttle to allow correlation of the VGS data with orbital best-estimate-of-truth data. The Video Guidance Sensor performed well in all phases of the testing, and the VGS is being incorporated into the ground testing of a complete automated rendezvous and docking system. Work on the development of the next generation VGS is continuing
Author
Cameras; Guidance Sensors; Orbital Rendezvous; Spacecraft Docking; Spacecraft Instruments; Rendezvous Guidance; Video Equipment

19990107381 NASA Marshall Space Flight Center, Huntsville, AL USA
Electrodynamic Tethers for Spacecraft Propulsion
Johnson, Les; Estes, Robert D.; Lorenzini, Enrico; Martinez-Sanchez, Manuel; Sanmartin, Juan; Vas, Irwin; [1998]; In English; 36th Aerospace Sciences, 12-15 Jan. 1998, Reno, NV, USA; No Copyright; Avail: Other Sources

Relatively short electrodynamic tethers can use solar power to 'push' against a planetary magnetic field to achieve propulsion without the expenditure of propellant. The groundwork has been laid for this type of propulsion. NASA began developing tether technology for space applications in the 1960's. Important recent milestones include retrieval of a tether in space (TSS-1, 1992), successful deployment of a 20-km-long tether in space (SEDS-1, 1993), and operation of an electrodynamic tether with tether current driven in both directions-power and thrust modes (PMG, 1993). The planned Propulsive Small Expendable Deployer System (ProSEDS) experiment will demonstrate electrodynamic tether thrust during its flight in early 2000. ProSEDS will use the flight-proven Small Expendable Deployer System (SEDS) to deploy a 5 km bare

copper tether from a Delta II upper stage to achieve approximately 0.4 N drag thrust, thus deorbiting the stage. The experiment will use a predominantly 'bare' tether for current collection in lieu of the endmass collector and insulated tether approach used on previous missions. Theory and ground-based plasma chamber testing indicate that the bare tether is a highly-efficient current collector. The flight experiment is a precursor to utilization of the technology on the International Space Station for reboost application and the more ambitious electrodynamic tether upper stage demonstration mission which will be capable of orbit raising, lowering and inclination changes - all using electrodynamic thrust. In addition, the use of this type of propulsion may be attractive for future missions at Jupiter and any other planetary body with a magnetosphere.
Author
Spacecraft Propulsion; Electrodynamics; Tethering; Orbital Rendezvous; Tetherlines; Rendezvous Guidance; Rendezvous Spacecraft; Spacecraft Docking

19990099112 NASA Marshall Space Flight Center, Huntsville, AL USA
Automated Rendezvous and Capture in Space: A Technology Assessment
Polites, Michael E.; Journal of Spacecraft and Rockets; [1998]; In English; No Copyright; Avail: Other Sources; Abstract Only;

This paper presents the results of a study to assess the technology of automated rendezvous and capture (AR&C) in space. The outline of the paper is as follows: First, the history of manual and automated rendezvous and capture and rendezvous and dock is presented. Next, the need for AR&C in space is reviewed. In light of these, AR&C systems are proposed that meet NASA's future needs, but can be developed in a reasonable amount of time with a reasonable amount of money. Technology plans for developing these systems are presented; cost and schedule are included.
Author
Rendezvous Guidance; Automated Transfer Vehicle; Spacecraft Guidance; Space Navigation; Autonomous Navigation; Automatic Flight Control

19990097316 NASA Marshall Space Flight Center, Huntsville, AL USA
Automatic Docking System Sensor Design, Test, and Mission Performance
Jackson, John L.; Howard, Richard T.; Cole, Helen J.; [1998]; In English, 13-17 Apr. 1998, Orlando, FL, USA; No Copyright; Avail: Other Sources; Abstract Only;

The Video Guidance Sensor is a key element of an automatic rendezvous and docking program administered by NASA that was flown on STS-87 in November of 1997. The system used laser illumination of a passive target in the field of view of an on-board camera and processed the video image to determine the relative position and attitude between the target and the sensor. Comparisons of mission results with theoretical models and laboratory measurements will be discussed.
Author
Spacecraft Docking; Mathematical Models; Lasers; Guidance Sensors; Cameras

19990089680 NASA Marshall Space Flight Center, Huntsville, AL USA
Video Guidance Sensor Flight Experiment Results
Howard, Richard T.; Bryan, Thomas C.; Book, Michael L.; 1998; In English, 13-17. 1998, Orlando, FL, USA; Copyright; Avail: Other Sources; Abstract Only

NASA's Marshall Space Flight Center flew on the STS-87 mission an active sensor system, the Video Guidance Sensor (VGS), to demonstrate its functioning in space and to collect performance data. The VGS was designed to provide near-range sensor data as part of an automatic rendezvous and docking system. The sensor determines the relative positions and attitudes between the active sensor and the passive target. The VGS uses laser diodes to illuminate retro-reflectors in the target, a solid-state camera to detect the return from the target, and a frame grabber and digital signal processor to convert the video information into the relative positions and attitudes. The system is designed to operate with the target within a relative azimuth of +/- 9.5 degrees and a relative elevation of +/- 7.5 degrees. The system will acquire and track the target within that field-of-view anywhere from 1.5 meters to 110 meters range, and is designed to acquire at relative attitudes of +/- 10 degrees in pitch and yaw and at any roll angle. The data is output from the sensor at 5 Hz, and the target and sensor software have been designed to permit two independent sensors to operate simultaneously (in order to allow for redundancy). The data from the flight experiment includes raw video data from the VGS camera, relative position and attitude measurements from the VGS to the target, independent hand-held laser ranges from the Shuttle Aft Flight Deck to the target, and Remote Manipulator System position data to correlate with the VGS data. The experiment was quite successful and returned much useful

information. The experience gained from the design and flight of this experiment will lead to improved video sensors in the future.
Author
Video Data; Guidance Sensors; Optical Measuring Instruments; Spacecraft Instruments; Video Signals

19990072352 NASA Marshall Space Flight Center, Huntsville, AL USA
Design of the Automated Rendezvous and Capture Docking System
Cruzen, Craig A.; Lomas, James J.; 1999; In English, 25-28 Apr. 1999, Houston, TX, USA
Contract(s)/Grant(s): RTOP 242-70-05; Copyright; Avail: Other Sources; Abstract Only;

This paper describes the Automated Rendezvous and Capture (AR&C) system that was designed and is being tested at NASA's Marshall Space Flight Center (MSFC). The AR&C system incorporates some of the latest innovations in Global Positioning System (GPS), laser sensor technologies and automated mission sequencing algorithms as well as the capability for ground and crew monitoring and commanding. This paper summarizes the variety of mission scenarios supported by the AR&C system. It also describes the major components of the AR&C system including the Guidance, Navigation and Control system, GPS receivers, relative navigation filter and the Video Guidance Sensor. A discussion of the safety and reliability issues confronted during the design follows. By designing a safe and robust automated system, space mission operations cost can be reduced by decreasing the number of ground personnel required for the extensive mission design, preflight planning and training typically required for rendezvous and docking missions.
Author
Orbital Rendezvous; Spacecraft Docking; Design Analysis

19990070948 NASA Marshall Space Flight Center, Huntsville, AL USA
The Video Guidance Sensor- A Flight Proven Technology
Howard, Richard T.; Bryan, Thomas C.; Book, Michael L.; Dabney, Richard W.; 1999; In English, 3-7 Feb. 1999, Breckenridge, CO, USA; Copyright; Avail: Other Sources; Abstract Only

The Video Guidance Sensor (VGS) flew on Shuttle mission STS-95 in October of 1998 to test the VGS functional characteristics on orbit. This was the second flight of the VGS, and during these two flights, both long range and short range data were gathered under a variety of lighting conditions, orbital exposure times, and temperatures. The flight experiment sensor was designed to operate from 1.5 meter range out to 110 meter range, with a field-of-view of 16 X 21 degrees. The VGS tracked its target at a 5 Hz rate and returned 6-degree-of-freedom information on the target's position and attitude relative to the sensor. The VGS was mounted in the Shuttle cargo bay, and its target was mounted on the Spartan spacecraft being carried on this mission. The VGS is a sensor designed to allow an automated vehicle to dock with a spacecraft equipped with a passive target. The VGS is a part of an Automated Rendezvous and Capture (AR&C) system being developed and tested by NASA. The orbital testing included operations with the target on the Shuttle's Remote Manipulator System (RMS) near the start of each flight of the VGS, long-range data (on the STS-95 flight) during the Shuttle rendezvous with the Spartan two days later, and some more RMS operations later in the mission. The data returned from the orbital testing included VGS diagnostics, acquisition, and tracking data, RMS positions, hand-held laser range data, tapes of the data from the VGS video camera, and orbital positioning data from the Spartan and the Shuttle to allow correlation of the VGS data with orbital best-estimate-of-truth data. The Video Guidance Sensor performed well in all phases of the testing, and the VGS is being incorporated into the ground testing of a complete automated rendezvous and docking system. Work on the development of the next generation VGS is continuing.
Author
Guidance Sensors; Space Missions; Video Equipment; Spacecraft Instruments

19980219470 NASA Marshall Space Flight Center, Huntsville, AL USA
An Assessment of the Technology of Automated Rendezvous and Capture in Space
Polites, M. E.; Jul. 1998; In English
Report No.(s): NASA/TP-1998-208528; M-877; NAS 1.60:208528; No Copyright; Avail: CASI; A04, Hardcopy

This paper presents the results of a study to assess the technology of automated rendezvous and capture (AR&C) in space. The outline of the paper is as follows. First, the history of manual and automated rendezvous and capture and rendezvous and dock is presented. Next, the need for AR&C in space is established. Then, today's technology and ongoing technology efforts related to AR&C in space are reviewed. In light of these, AR&C systems are proposed that meet NASA's future needs, but

can be developed in a reasonable amount of time with a reasonable amount of money. Technology plans for developing these systems are presented; cost and schedule are included.
Author
Automated Transfer Vehicle; Technology Assessment; Capture Effect; Rendezvous

19980201715 Rocket Space Corp. Energia, Korlev, Russia
Analysis of docking operations experience of the progress vehicles and the Mir station using teleoperator control mode
Matveeva, T. V.; AAS/GSFC 13th International Symposium on Space Flight Dynamics; May 1998; Volume 2; In English
Report No.(s): AAS Paper 98-383; No Copyright; Avail: Other Sources; Abstract Only

Teleoperator control mode (Russian acronym is TORU) was developed to enhance reliability of docking operations of the Progress transport cargo and the Mir orbital complex. In the cases of automatic mode failure while docking an operator can take up the motion control function and finish the docking manually. This operator may be either a member of the orbital station crew or a ground controller. Pros and cons of TORU mode are considered in this paper. Its advantages over other methods of docking reliability improvement are discussed. The final result of TORU mode usage mostly depends on correct planning of the docking operation. To take into account all the specific conditions, limitations and requirements is very important. This paper presents the basic principles of consideration TORU features during mission planning, which can be recommended for transport operations in the International Space Station (ISS) program. For the first time TORU mode was tested in 1993 during Progress M-15 and Progress M-16 missions. Since then this method was repeatedly checked in flight and was adopted as alternate nominal mode. The experience of docking operations of the Progress vehicles in the Mir station program is analyzed in this paper. The real facts from the Progress vehicles planning practice are given. TORU mode has attracted considerable attention on the 25th of June 1997 when the collision between Progress vehicle and the Mir orbital complex occurred. This paper presents short analysis of that off-nominal situation together with the demonstration of computer animation of mutual vehicle and station motion.
Author
Teleoperators; Spacecraft Docking; Mir Space Station; Automatic Control; Controllers

19980193167 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
Compact drilling and sample system
Gillis-Smith, Greg R.; Petercsak, Doug; Fortieth Anniversary: Pioneering the Future; May 1998; In English; No Copyright; Avail: CASI; A03, Hardcopy

The Compact Drilling and Sample System (CDSS) was developed to drill into terrestrial, cometary, and asteroid material in a cryogenic, vacuum environment in order to acquire subsurface samples. Although drills were used by the Apollo astronauts some 20 years ago, this drill is a fraction of the mass and power and operates completely autonomously, able to drill, acquire, transport, dock, and release sample containers in science instruments. The CDSS has incorporated into its control system the ability to gather science data about the material being drilled by measuring drilling rate per force applied and torque. This drill will be able to optimize rotation and thrust in order to achieve the highest drilling rate possible in any given sample. The drill can be commanded to drill at a specified force, so that force imparted on the rover or lander is limited. This paper will discuss the cryo dc brush motors, carbide gears, cryogenic lubrication, quick-release interchangeable sampling drill bits, percussion drilling and the control system developed to achieve autonomous, cryogenic, vacuum, lightweight drilling.
Author
Drills; Mechanical Devices; Tools; Drilling; Electric Motors; Gears; Drill Bits; Automatic Control; Lubrication Systems

19980137256 Energiya Rocket-Space Corp., Kaliningrad, Russia
Dynamic schemes optimization for scientific experiments and different flight operations on board the Mir orbital complex
Tereshina, I. N.; Stazhkov, V. M.; Aug. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy

The development of dynamic schemes for the different flight phases of the Mir space station is discussed. The following phases and operations are considered: research experiments; docking operations, and communications via relay satellites. The conditions and limitations related to the power supply, the thermal control systems and guidance, navigation and control systems that must be taken into account for these operations, are described. Dynamic scheme optimization criteria include the choice of optimum time intervals for the execution of experiments, the minimization of propellant consumption during the performance of different mission operations and the choice of when to perform an attitude alteration maneuver. The following tasks are performed for the development of the dynamic schemes: the prediction of power balance during the mission

operations; the determination of the durations of altitude alteration maneuvers; the prediction of propellant consumption during the gyrosystem desaturation; the prediction of thruster operation moments, and the prediction of the thermal control system operation.
Author (ESA)
Mir Space Station; Spacecraft Maneuvers; Attitude Control; Operations Research

19980137199 MATRA Marconi Space, Toulouse, France
RGPS postflight analysis of ARP-K flight demonstration
Moreau, Gerard; Marcille, Herve; Aug. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy

The ESA's automated transfer vehicle (ATV) rendezvous pre-development (ARP) program demonstrates the key technologies involved in the navigation of the ATV to rendezvous with the International Space Station (ISS). The pre-development program aims to develop a full scale prototype of the navigation software based on the candidate sensors of the ATV candidate sensors in the ARP global positioning system (GPS) receiver and the optical rendezvous sensor. This involves the development and validation of a relative GPS (RGPS) filter for the provision of relative navigation information based on the data from the ATV's and the ISS's GPS receivers. The flight testing of this system onboard the Space Shuttle during rendezvous operations is considered. The differences between the results obtained and those expected are discussed, together with their impact on the performance of the RGPS filter.
Author (ESA)
Global Positioning System; Automated Transfer Vehicle; Rendezvous Guidance; Postflight Analysis; Space Flight; Space Navigation

19980137198 European Space Agency. European Space Operations Center, Darmstadt, Germany
Absolute and relative navigation of spacecraft using GPS: The ATV rendezvous predevelopment flight demonstrations
Martin-Mur, Tomas J.; Dow, John M.; Garcia-Martinez, Carlos; Aug. 1997; In English; No Copyright; Avail: CASI; A01, Hardcopy

In relation to the future use of the global positioning system for the proximity navigation of the ESA automated transfer vehicle (ATV) near to the International Space Station, the demonstration of spacecraft-relative navigation using GPS is required. For this purpose, and within the framework of the ATV rendezvous pre-development project, a number of flight demonstrations using the NASA STS and another spacecraft are planned. The spacecraft will carry GPS receivers and the data collected will be used to validate the algorithms proposed for ATV relative navigation.
Author (ESA)
Global Positioning System; Spacecraft Guidance; Rendezvous Guidance; Automated Transfer Vehicle; Space Navigation; Flight Mechanics; Space Flight

19970023279 Grupo de Mecanica del Vuelo S.A., Madrid, Spain
MIMO control for six DoF relative motion
Mora, E. J.; Serrano, J. B.; Ankersen, F.; Feb. 1997; In English
Contract(s)/Grant(s): ESA-9982/92/NL/JG; No Copyright; Avail: CASI; A03, Hardcopy; US Distribution and Sales Only

Investigation into the control of the simultaneous translational and rotational six degree of freedom relative motion between two spacecraft with an arbitrary pointing is reported. The controller design and analysis are based on multi-input, multi-output (MIMO) control methods. Different MIMO control design techniques were reviewed and four were selected as the most promising ones: linear quadratic control; pole placement control; H-infinity synthesis, and mu synthesis. For the investigations, the automated transfer vehicle (ATV)-International Space Station (ISS) rendezvous and docking mission was selected as the baseline. The application of these techniques to two representative guidance, navigation and control (GNC) modes with different motions, references and target attitudes, is described.
Author (ESA)
MIMO (Control Systems); Rendezvous Guidance; Control Systems Design; Automated Transfer Vehicle; Orbital Rendezvous; Automatic Control

19970023267 Cosmonaut Training Center, CPK Star City, Russia
Remote intervention in automatic onboard GNC systems
Vankov, A.; Alyoshin, A.; Chliaev, P.; Fehse, W.; Feb. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

The results of research and development activities carried out on remote interaction concepts for automatic space vehicles during rendezvous operations are reported. The contingency situations during the approach of automated vehicles to a space station are reviewed together with the onboard resources available to overcome such situations and the possibilities of remote intervention in automatic onboard guidance, navigation and control (GNC) systems. The possibilities include various kinds of open loop and closed loop interaction. In order to investigate the various possibilities, a simulator was built which allows various situations and interaction methods to be considered. The scope and objectives of the simulator and the remote control concepts simulated are discussed and the corresponding operator interfaces are described. The various interaction concepts and the potential application of the results to the International Space Station are illustrated.
Author (ESA)
Automated Transfer Vehicle; International Space Station; Rendezvous Guidance; Remote Control; Autonomous Navigation; Spacecraft Guidance; Automatic Pilots; Feedback Control; Control Theory; Inertial Navigation

19970023266 Tsukuba Space Center, Japan
Rendezvous strategy of the Japanese logistics support vehicle to the International Space Station
Yamanaka, K.; Feb. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

The design of an automated transfer vehicle for the logistics support of the International Space Station by the National Space Development Agency of Japan (NASDA) is reported. This vehicle, the H-2 transfer vehicle (HTV) will be launched by the H-2A rocket. The long range rendezvous sequence consists of phase, height and plane adjustment maneuvers, and two elliptical intermediate orbits. Global positioning system (GPS) navigation is used for the long range rendezvous, with the implementation of differential GPS navigation for the final rendezvous approach and laser radar navigation from a distance of 500 m. It is planned to demonstrate the navigation, guidance and control functions of the vehicle within the framework of the 7th engineering test satellite (ETS-7) mission in 1997.
Author (ESA)
Automated Transfer Vehicle; International Space Station; Rendezvous Guidance; Global Positioning System; Japanese Spacecraft; Control Systems Design; Radar Navigation

19970023265 MATRA Marconi Space, Toulouse, France
ARPK GNC design and performances evaluation for ATV rendezvous
Gonnaud, Jean-Louis; Sommer, J.; Tsang, M.; Feb. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

The development of a prototype guidance, navigation, and control (GNC) software within the framework of the automated transfer vehicle (ATV) rendezvous predevelopment program kernel activities (ARPK) is reported. An integrated approach for the analysis, design and software implementation was followed based on computer aided design tools. The major tradeoffs implemented for the guidance and control design based on H-infinity synthesis and mu-analysis are described, together with the implementation of the selected concept in a Systembuild(TM) environment. The methodology used to statistically derive a set of performance files covering the ATV flight envelope during rendezvous is presented.
Author (ESA)
Automated Transfer Vehicle; International Space Station; Rendezvous Guidance; Global Positioning System; Control Systems Design; H-Infinity Control; Autonomous Navigation

19970023264 MATRA Marconi Space, Toulouse, France
ATV GNC during rendezvous
Fabrega, Josian; Frezet, Michel; Gonnaud, Jean-Louis; Feb. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

The ESA's automated transfer vehicle (ATV) program is considered with emphasis on the ATV's capability to autonomously rendezvous and dock with the International Space Station. The ATV program is currently in phase B of its development, whereas phase C/D including the detailed design and construction of the first flight model is planned to start in 1997 and a first flight is scheduled for 2002. The major results of the phase B are reported on in relation to the determination of a baseline for the guidance, navigation and control (GNC) functions of the ATV during the rendezvous and docking procedures. It is concluded that the current baseline depends on critical assumptions and data: common global positioning system (GPS) antenna orientation between the two vehicles; functional twin GPS receivers on the two vehicles; the docking

condition requirements are imposed by the Space Station; the Space Station's dynamic conditions; and assumptions concerning common mode failures.
Author (ESA)
Automated Transfer Vehicle; International Space Station; Rendezvous Guidance; Global Positioning System; Orbital Rendezvous; Autonomous Navigation; Spacecraft Docking; Spacecraft Guidance

19970023263 MATRA Marconi Space, Toulouse, France
Relative GPS navigation design and validation for ATV rendezvous
Marcille, Herve; Moreau, Gerard; Pascal, Virginie; Feb. 1997; In English; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

Through the automated transfer vehicle (ATV) rendezvous predevelopment (ARP) program, ESA aims to demonstrate European expertise concerning the critical technologies involved in the achievement of autonomous rendezvous and docking of the ATV to the International Space Station. Within the framework of this program, a global positioning system (GPS)-based relative navigation system (RGPS) was developed for use as the primary navigation reference for the long-range proximity operations. The baseline concept is based on Kalman filter processing of the simultaneous data from two receivers located on the two vehicles. The results obtained in the RGPS development program and from the validation activities are reported.
Author (ESA)
Automated Transfer Vehicle; International Space Station; Rendezvous Guidance; Global Positioning System; Autonomous Navigation

19970023253 European Space Agency, Paris France
The Third ESA International Conference on Spacecraft Guidance, Navigation and Control Systems and Tutorial on Microstats: Design, Development and Execution of Minimum Missions
Kaldeich-Schuermann, Brigitte, compiler; Proceedings of 3rd ESA International Conference on Spacecraft Guidance, Navigation and Control Systems and Tutorial on Microstats: Design, Development and Execution of Minimum Missions; Feb. 1997; In English; In French, 26-29 Nov. 1996, Noordwijk, Netherlands
Report No.(s): ESA-SP-381; No Copyright; Avail: CASI; A99, Hardcopy; US Distribution and Sales Only

The following aspects of spacecraft attitude and orbit control systems (AOCS) and guidance, navigation and control (GNC) systems are reported: in-flight experience of these systems; star sensor systems and design; the use of the global positioning system (GPS); rendezvous navigation and control; systems for specific spacecraft and missions; reentry navigation and control; instrument pointing and drag free control; GPS hardware for spacecraft; launch vehicle navigation and control; spacecraft landing and planetary missions; high accuracy pointing systems; and small satellite technology.
Author (ESA)
Satellite Attitude Control; Pointing Control Systems; Conferences; Spacecraft Guidance; Autonomous Navigation; Control Systems Design; Spacecraft Electronic Equipment; Systems Engineering

19970022338 Bristol Univ., UK
The impact of GPS on rendezvous times
Morris, Oliver; Patterson, Janice; May 1996; In English
Report No.(s): Rept-772; No Copyright; Avail: CASI; A04, Hardcopy; US Distribution and Sales Only

Many future space missions will be for rendezvous with the International Space Station. The reduction of the flight time to rendezvous which currently requires two days would provide scheduling and commercial benefits. It is known that rendezvous times can be cut to a few hours if the phasing section of the rendezvous is excluded. This exclusion would require very accurate flight guidance. The assessment of the possibility of such fast rendezvous guidance using the global positioning system (GPS) as the only means of guidance is reported on. A simulation was developed to provide a stochastic model of a single stage to orbit spacecraft's launch and orbital maneuvering. It is concluded that an accuracy of 60 km at rendezvous is obtained which deteriorates with the accuracy of the maneuver rockets, the launch timing and injection.
Author (ESA)
Rendezvous Guidance; Global Positioning System; Orbital Rendezvous

19970017115 Energiya Rocket-Space Corp., Kaliningrad Russia
Attitude simulation during MIR orbital complex flight
Tereshina, I. N.; Teslenko, V. P.; Manzheley, A. I.; Proceedings of 4th International Symposium on Space Mission Operations and Ground Data Systems, volume 2; Nov. 1996; Volume 2; In English
Report No.(s): Paper SO96.5.20; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

Issues related to the Mir space station attitude selection for different flight operations and phases, are discussed. These operations and phases include: onboard experimentation; the docking, redocking and undocking of crew and cargo transport spacecraft; and communications. The conditions and limitations for the implementation of these attitude control modes, driven by the Mir orbital complex guidance, navigation and control system, the power supply and the thermal control system, are described.
Author (ESA)
Mir Space Station; Attitude (Inclination); Satellite Attitude Control; Flight Operations

19970016414 National Air Intelligence Center, Wright-Patterson AFB, OH, USA
Selected Articles
Proceedings of the Symposium on Photoelectric Technology; Jan. 14, 1997, No. 9; In English
Contract(s)/Grant(s): F33657-87-D-0096
Report No.(s): AD-A320855; NAIC-ID(RS)T-0397-96; No Copyright; Avail: CASI; A05, Hardcopy
This report includes: (1) The Comparison of The Parallel Scanning And Serial Scanning Scheme of The Optical Mechanical Scanning Infrared Imaging System, (2) The Laser Weapon Development State in Foreign Countries, (3) Space Rendezvous and Docking Navigation Survey Sensor RVD Laser Radar Survey System, (4) Missile's Guidance Head Anti-Nuclear Electromagnetic Pulse Reinforcement, and (5) Land Based Guided Missile Anti-Thermal Infrared Camouflage Net Research.
DTIC
Infrared Imagery; Optical Scanners; Laser Weapons; Space Rendezvous; Space Navigation; Electromagnetic Shielding; Optical Radar

19970016255 TRASYS Space, Brussels, Belgium
The architectural design of the ATV control centre: Results of the phase B study
De Weer, D.; Lamberti, F.; Fourth International Symposium on Space Mission Operations and Ground Data Systems; Nov. 1996; Volume 1; In English
Report No.(s): Paper-SO96.2.008; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only
The results of the design study for the definition of the preliminary architecture of the automated transfer vehicle (ATV) control center are presented. The control center is intended to support the ATV during all mission phases, and to provide coordination and authority transfer between the centers involved in the different mission phases. The ATV mission and system are outlined together with the design drivers for the control center. The conclusions of the study are that the control center: is designed to fulfill a number of requirements of different nature; reuses a large number of existing tools; is designed to cope with a highly autonomous spacecraft, and can evolve the architecture due to future changes in concepts, requirements or technologies.
Author (ESA)
Automated Transfer Vehicle; Spacecraft Control; Control Systems Design; Rendezvous Guidance

19970016246 European Space Agency. European Space Operations Center, Darmstadt, Germany
A knowledge based system to support the operator in ATV rendezvous mission with the International Space Station
Donati, A.; Romani, E.; Fourth International Symposium on Space Mission Operations and Ground Data Systems; Nov. 1996; Volume 1; In English
Report No.(s): Paper-SO96.1.019; No Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only
A prototype flight operator support environment, which can be used within the mission control system of the automated transfer vehicle (ATV) rendezvous missions, is described. The environment implements the concept of a vehicle expert module. The prototype was developed using a commercial real-time knowledge-based platform which is compatible with the NASA knowledge based system environment and consists of: object oriented models of the ATV and its mission; a rule-based diagnostic system, and a telemetry generator and failure simulator. The prototype is able to support a flight controller of a rendezvous mission by providing the following functions: synthetic advanced monitoring; safe status checks and evaluation; fault prevention; early diagnosis; fault detection and isolation; fault recovery; and resource consumption evaluations.
Author (ESA)
Spacecraft Control; Automated Transfer Vehicle; Knowledge Based Systems; Spacecraft Guidance; Control Systems Design; Real Time Operation

19970013816 Stafford (Thomas P.), Unknown

Fifth Report of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions

Sep. 21, 1995; In English

Report No.(s): NASA-TM-112697; NAS 1.15:112697; No Copyright; Avail: CASI; A07, Hardcopy

The NASA Advisory Council Task Force on the Shuttle-Mir rendezvous and docking missions examine a number of specific issues related to the Shuttle-Mir program. Three teams composed of Task Force members and technical advisors were formed to address the follow issues: preliminary results from STS-71 and the status of preparations for STS-74; NASA's presence in Russia; and NASA's automated data processing and telecommunications (ADP/T) infrastructure in Russia. The three review team reports have been included in the fifth report of the Task Force.

CASI

Mission Planning; Orbital Rendezvous; Spacecraft Docking; Mir Space Station; Space Transportation System Flights; Space Shuttle Missions; Recommendations

19970005303 Texas Univ., El Paso, TX USA

Space-Related Applications of Intelligent Control: Which Algorithm to Choose? (Theoretical Analysis of the Problem)

Kreinovich, Vladik; 1996; In English

Contract(s)/Grant(s): NAG9-757

Report No.(s): NASA-CR-202660; NAS 1.26:202660; No Copyright; Avail: CASI; A03, Hardcopy

For a space mission to be successful it is vitally important to have a good control strategy. For example, with the Space Shuttle it is necessary to guarantee the success and smoothness of docking, the smoothness and fuel efficiency of trajectory control, etc. For an automated planetary mission it is important to control the spacecraft's trajectory, and after that, to control the planetary rover so that it would be operable for the longest possible period of time. In many complicated control situations, traditional methods of control theory are difficult or even impossible to apply. In general, in uncertain situations, where no routine methods are directly applicable, we must rely on the creativity and skill of the human operators. In order to simulate these experts, an intelligent control methodology must be developed. The research objectives of this project were: to analyze existing control techniques; to find out which of these techniques is the best with respect to the basic optimality criteria (stability, smoothness, robustness); and, if for some problems, none of the existing techniques is satisfactory, to design new, better intelligent control techniques.

Derived from text

Algorithms; Control Systems Design; Control Theory; Space Missions; Mission Planning; Fuzzy Systems; Design Analysis; Space Exploration

19970001337 NASA Johnson Space Center, Houston, TX USA

Flight Test Results from Real-Time Relative Global Positioning System Flight Experiment on STS-69

Park, Young W.; Brazzel, Jack P., Jr.; Carpenter, J. Russell; Hinkel, Heather D.; Newman, James H.; Nov. 1996; In English

Report No.(s): NASA-TM-104824; S-821; NAS 1.15:104824; No Copyright; Avail: CASI; A03, Hardcopy

A real-time global positioning system (GPS) Kalman filter has been developed to support automated rendezvous with the International Space Station (ISS). The filter is integrated with existing Shuttle rendezvous software running on a 486 laptop computer under Windows. In this work, we present real-time and postflight results achieved with the filter on STS-69. The experiment used GPS data from an Osborne/Jet propulsion Laboratory TurboRouge receiver carried on the Wake Shield Facility (WSF) free flyer and a Rockwell Collins 3M receiver carried on the Orbiter. Real time filter results, processed onboard the Shuttle and replayed in near-time on the ground, are based on single vehicle mode operation and on 5 to 20 minute snapshots of telemetry provided by WSF for dual-vehicle mode operation. The Orbiter and WSF state vectors calculated using our filter compare favorably with precise reference orbits determined by the University of Texas Center for Space Research. The lessons learned from this experiment will be used in conjunction with future experiments to mitigate the technology risk posed by automated rendezvous and docking to the ISS.

Author

Global Positioning System; Space Transportation System Flights; International Space Station; Spacecraft Docking; Real Time Operation; Kalman Filters; Rendezvous Guidance

19960052919 NASA Johnson Space Center, Houston, TX USA

A Magnetic Bumper-Tether System Using ZFC Y123

Weinstein, Roy; Parks, Drew; Sawh, Ravi-Persad; Obot, Victor; Liu, Jianxiong; Arndt, G. D.; Third International Symposium on Magnetic Suspension Technology; Jul. 1996; Part 1; In English; No Copyright; Avail: CASI; A02, Hardcopy

We consider the use of magnetic forces in a bumper system, to soften docking procedures. We investigate a system which exhibits no magnetic field except during the docking process, which, if desired, can automatically tether two craft together, and which provides lateral stability during docking. A system composed of zero field cooled Y(1.7)Ba2Cu3O(7-delta) (Y123) tiles and electromagnets is proposed. The Y123 high temperature superconductor (HTS) is mounted on one craft, and the electromagnet on the other. Results of small prototype laboratory experiments are reported. The electromagnet has, for convenience, been replaced by a permanent SmCo ferromagnet in these measurements. When the two craft approach, a mirror image of the ferromagnet is induced in the Y123, and a repulsive bumper force, F(sub B), results. F(sub B) is velocity dependent, and increases with v. For presently available HTS materials, bumper pressure of approx. 3.7 N/cm(exp 2) is achieved using SmCo. This extrapolates to approx. 18 N/cm(exp 2) for an electromagnet, or a force of up to 20 tons for a 1 m(exp 2) system. After reaching a minimum distance of approach, the two colliding craft begin to separate. However, the consequent change of SmCo magnetic field at the Y123 results in a reversal of current in the Y123 so that the Y123 is attractive to the SmCo. The attractive (tether) force, F(sub T), is a function of R = B(sub Fe)/B(sub t, max), where B(sub Fe) is the field at the surface of the ferromagnet, and B(sub t, max) is the maximum trapped field of the Y123, i.e., the trapped field in the so-called critical state. For R greater than or equal to 2, F(sub T) saturates at a value comparable to F(sub B). For a range of initial approach velocities the two craft are tethered following the bumper sequence. Most of the kinetic energy of the collision is first converted to magnetic field energy in the Y123, and then into heat via the creep mechanism. About 15% of the work done against magnetic forces during collision remains stored as magnetic energy after 1 hour. Experiments have also been conducted on the spatial range of the bumper force for arrays of HTS tiles. For a single HTS tile approx. 2 cm in diameter, the range of F(sub B) is approx. l cm. For a l m(exp 2) array the range of F(sub B) will be circa 50 cm.
Author
Spacecraft Docking; Electromagnets; YBCO Superconductors; Trapped Magnetic Fields; Loads (Forces)

19960049785 National Air Intelligence Center, Wright-Patterson AFB, OH, USA
Applications of GPS During Spacecraft Rendezvous and Docking
Qun, Fang; Feng, Zeng; Journal of Astronautics; Mar. 14, 1996; Volume 16, No. 2; In English
Report No.(s): AD-A306503; NAIC-ID(RS)T-0013-96; No Copyright; Avail: CASI; A03, Hardcopy

Satellite positioning and satellite communications are in the midst of the initial selection phase of telemetry and control, looking for an advanced autonomous rendezvous system. This article summarizes basic requirements and processes associated with spacecraft rendezvous and docking as well as the composition of the U.S. global positioning system (GPS), the principles of positioning, precision, and difference principles, after which it sets out two types of relative motion equation forms. Making use of a combination of motion equation solutions, pure GPS, and difference GPS, it is possible to complete the entire guidance process of tracking spacecraft approaching target spacecraft. Moreover, it is possible to economize on such equipment as enormous ground telemetry and remote control, radars on board satellites, and so on, reducing sources of error. Simulation calculations verify that this design concept is feasible and accurate.
DTIC
Space Rendezvous; Spacecraft Docking; Spacecraft Guidance; Global Positioning System; Satellite Communication; Positioning

19960047555 NASA, Moffett Field, CA USA
Neural Networks for Flight Control
Jorgensen, Charles C.; Computational Intelligence and Its Impact on Future High-Performance Engineering Systems; Jan. 1996; In English; No Copyright; Avail: CASI; A03, Hardcopy

Neural networks are being developed at NASA Ames Research Center to permit real-time adaptive control of time varying nonlinear systems, enhance the fault-tolerance of mission hardware, and permit online system reconfiguration. In general, the problem of controlling time varying nonlinear systems with unknown structures has not been solved. Adaptive neural control techniques show considerable promise and are being applied to technical challenges including automated docking of spacecraft, dynamic balancing of the space station centrifuge, online reconfiguration of damaged aircraft, and reducing cost of new air and spacecraft designs. Our experiences have shown that neural network algorithms solved certain problems that conventional control methods have been unable to effectively address. These include damage mitigation in nonlinear reconfiguration flight control, early performance estimation of new aircraft designs, compensation for damaged planetary mission hardware by using redundant manipulator capability, and space sensor platform stabilization. This presentation explored these developments in the context of neural network control theory. The discussion began with an overview of why neural control has proven attractive for NASA application domains. The more important issues in control system development were then discussed with references to significant technical advances in the literature. Examples of how these methods have

been applied were given, followed by projections of emerging application needs and directions.
Derived from text
Neural Nets; Network Control; Space Missions; Systems Engineering; Real Time Operation; On-Line Systems; Flight Control; Control Systems Design; Adaptive Control; Automatic Control

19960042912 Raumfahrt Systemtechnik G.m.b.H., Rostock, Germany, Deutsche Aerospace A.G., Rostock, Germany, Entwicklungsring Nord, Bremen, Germany, Jenoptik Jena G.m.b.H., German Democratic Republic, KSP Ingenieurtechnische Dienste G.m.b.H., Chemnitz, Germany
Software development for RvD. Requirement analysis of subsystems for DUSE. Documentation, Part 2
[1995]; In German; In English
Contract(s)/Grant(s): BMFT-50IP9202; No Copyright; Avail: Other Sources

In the scope of the Pre-Development Program (PDP) a simulator called ROSS (Rendezvous Onboard System Simulator) has been developed. This software tool allows the analyses of both GNC performance and operational aspects (system observability and supervisory control). Functionally, it consists of two major components, the onboard software (RVC, Rendezvous Control software) and the environment simulation (RVV, Rendezvous Verification software), the first of which subdivides into Mission and Vehicle Management (MVM) and the GNC algorithms. The present document is the Architectural Design Document (ADD) for the Mission and Vehicle Management functions. According to the Object Oriented Design goal, without the utilization of a powerful but expensive Software Design Environment (SDE), the architecture follows a HOOD like methodology as described in the software design standards. Each object is partitioned in description, informal solution strategy and design specification. The description part is written such that it may serve as a detailed concept description of the MVM, and the design specification can be extended later such that this document becomes Detailed Design Document (DDD), i.e. all internal functions are addressed and described.
Author (FIZ)
Space Missions; Systems Management; Space Rendezvous; Simulators; Software Engineering

19960034310 NASA Marshall Space Flight Center, Huntsville,AL USA
Global Positioning System Synchronized Active Light Autonomous Docking System
Howard, Richard T., Inventor; Book, Michael L., Inventor; Bryan, Thomas C., Inventor; Bell, Joseph L., Inventor; Feb. 06, 1996; In English
Patent Info.: Filed 1 Aug. 1994; US-Patent-5,490,075; US-Patent-Appl-SN-283728; NASA-Case-MFS-28853-1
Report No.(s): US-Patent-Class-364-459; US-Patent-Class-364-424.02; Int-Patent-Class-B64G-1/64; No Copyright; Avail: US Patent and Trademark Office

A Global Positioning System Synchronized Active Light Autonomous Docking System (GPSSALADS) for automatically docking a chase vehicle with a target vehicle comprising at least one active light emitting target which is operatively attached to the target vehicle. The target includes a three-dimensional array of concomitantly flashing lights which flash at a controlled common frequency. The GPSSALADS further comprises a visual tracking sensor operatively attached to the chase vehicle for detecting and tracking the target vehicle. Its performance is synchronized with the flash frequency of the lights by a synchronization means which is comprised of first and second internal clocks operatively connected to the active light target and visual tracking sensor, respectively, for providing timing control signals thereto, respectively. The synchronization means further includes first and second Global Positioning System receivers operatively connected to the first and second internal clocks, respectively, for repeatedly providing simultaneous synchronization pulses to the internal clocks, respectively. In addition, the GPSSALADS includes a docking process controller means which is operatively attached to the chase vehicle and is responsive to the visual tracking sensor for producing commands for the guidance and propulsion system of the chase vehicle.
Official Gazette of the U.S. Patent and Trademark Office
Global Positioning System; Spacecraft Docking; Luminaires; Frequency Synchronization

19960025430 Tuskegee Research Inst., AL USA
Triangulation methods for automated docking
Bales, John W.; Research Reports: 1995 NASA/ASEE Summer Faculty Fellowship Program; Feb. 1996; In English; No Copyright; Avail: CASI; A02, Hardcopy

An automated docking system must have a reliable method for determining range and orientation of the passive (target) vehicle with respect to the active vehicle. This method must also provide accurate information on the rates of change of range

to and orientation of the passive vehicle. The method must be accurate within required tolerances and capable of operating in real time. The method being developed at Marshall Space Flight Center employs a single TV camera, a laser illumination system and a target consisting, in its minimal configuration, of three retro-reflectors. Two of the retro-reflectors are mounted flush to the same surface, with the third retro-reflector mounted to a post fixed midway between the other two and jutting at a right angle from the surface. For redundancy, two additional retroreflectors are mounted on the surface on a line at right angles to the line containing the first two retro-reflectors, and equally spaced on either side of the post. The target vehicle will contain a large target for initial acquisition and several smaller targets for close range.
Derived from text
Spacecraft Docking; Target Acquisition; Automatic Control; Real Time Operation; Tracking (Position); NASA Programs; University Program

19960021758 NASA Johnson Space Center, Houston,TX USA
Multi-Flight-Phase GPS Navigation Filter Applications to Terrestrial Vehicle Navigation and Positioning
Park, Young W.; Montez, Moises N.; Dual-Use Space Technology Transfer Conference and Exhibition; May 1994; Volume 1; In English; No Copyright; Avail: CASI; A02, Hardcopy

A candidate onboard space navigation filter demonstrated excellent performance (less than 8 meter level RMS semi-major axis accuracy) in performing orbit determination of a low-Earth orbit Explorer satellite using single-frequency real GPS data. This performance is significantly better than predicted by other simulation studies using dual-frequency GPS data. The study results revealed the significance of two new modeling approaches evaluated in the work. One approach introduces a single-frequency ionospheric correction through pseudo-range and phase range averaging implementation. The other approach demonstrates a precise axis-dependent characterization of dynamic sample space uncertainty to compute a more accurate Kalman filter gain. Additionally, this navigation filter demonstrates a flexibility to accommodate both perturbational dynamic and observational biases required for multi-flight phase and inhomogeneous application environments. This paper reviews the potential application of these methods and the filter structure to terrestrial vehicle and positioning applications. Both the single-frequency ionospheric correction method and the axis-dependent state noise modeling approach offer valuable contributions in cost and accuracy improvements for terrestrial GPS receivers. With a modular design approach to either 'plug-in' or 'unplug' various force models, this multi-flight phase navigation filter design structure also provides a versatile GPS navigation software engine for both atmospheric and exo-atmospheric navigation or positioning use, thereby streamlining the flight phase or application-dependent software requirements. Thus, a standardized GPS navigation software engine that can reduce the development and maintenance cost of commercial GPS receivers is now possible.
Author
Global Positioning System; Onboard Equipment; Space Navigation; Rendezvous Guidance; Orbit Calculation; Spacecraft Guidance; Kalman Filters; Systems Integration; Trajectory Analysis; Applications Programs (Computers)

19960017247 National Air Intelligence Center, Wright-Patterson AFB, OH, USA
Designing of a Nonlinear Optimal Terminal Guidance Law for Space Interception
Xiaoping, Shi; Zicai, Wang; Oct. 13, 1995; In English
Contract(s)/Grant(s): F33657-84-D-0165
Report No.(s): AD-A300855; NAIC-ID(RS)T-0228-95; No Copyright; Avail: CASI; A03, Hardcopy

This article concerns a nonlinear kinematics model of space interception. Nonlinear optimal control is sought through use of inverse systematic methods. A theoretical nonlinear terminal guidance law of global state feedback is advanced. In addition, a simulation test is carried out and a comparison is made with proportional guidance. Results show that this guidance law performs satisfactorily.
DTIC
Rendezvous Guidance; Optimal Control; Terminal Guidance; Nonlinear Systems; Trajectory Control; Satellite Interceptors; Interception; Pursuit Tracking

19960013864 National Air Intelligence Center, Wright-Patterson AFB, OH, USA
Development of the control theories and methods for optimal rendezvous in space
Sep 14, 1995; In English
Contract(s)/Grant(s): F33657-84-D-0165
Report No.(s): AD-A300672; NAIC-ID(RS)T-0264-95; No Copyright; Avail: CASI; A03, Hardcopy

This article describes in a general way optimal rendezvous control theories and methods inside and outside China. It

stresses a discussion of progress in China in the last few years. It introduces the results of research on the theories and methods of adjacent near circular orbit optimal rendezvous under the effects of finite thrusts, ordinary coplanar elliptical orbit general optimal rendezvous, multiple pulse thrust linearized and nonlinear rendezvous orbital optimal guidance and horizontal impulse thrust optimal rendezvous control.
DTIC
Control Theory; Optimal Control; Orbital Rendezvous; Rendezvous Guidance; Thrust Control

19960009797 Foreign Broadcast Information Service, Washington, DC, USA, Foreign Broadcast Information Service, Washington, DC, USA
Optimum four-pulse rendezvous on coplanar near-circular orbits
Baranov, A. A.; Terekhova, Ye. O.; FBIS Report: Science and Technology. Central Eurasia: Mir and Other Russian Spacecraft Orbits Examined; Oct 27, 1995; In English; Copyright; Avail: Other Sources

The four-pulse maneuvers that ensure the rendezvous of two spacecraft initially moving in close near-circular coplanar orbits are considered in the linear formulation. Plots of the angles of application of pulses and their orientation are plotted as a function of the angular range of transfer for solutions that satisfy the necessary conditions of optimality. Simple analytical relations are proposed that coincide fairly accurately with the numerical plots. The effectiveness of the proposed method is demonstrated by solution of the problem of rendezvous of spacecraft initially moving in the same circular orbit.
Author (revised)
Circular Orbits; Earth Orbital Rendezvous; Optimal Control; Rendezvous Guidance; Rendezvous Spacecraft; Rendezvous Trajectories

19960009793 Foreign Broadcast Information Service, Washington, DC, USA, Foreign Broadcast Information Service, Washington, DC, USA
FBIS report: Science and technology. Central Eurasia: Mir and other Russian spacecraft orbits examined
Oct 27, 1995; In English; See also N96-16960 through N96-16964
Report No.(s): FBIS-UST-95-043; NIPS-96-06041; Copyright; Avail: Other Sources

In this special FBIS report, translated articles relating to the Mir space station and other Russian spacecraft orbits are presented.
CASI
Circular Orbits; Earth Orbits; Extraterrestrial Radiation; Flexible Spacecraft; Geosynchronous Orbits; Maneuverable Spacecraft; Mir Space Station; Russian Space Program; Transfer Orbits

19960007716 Joint Inst. for Advancement of Flight Sciences, Hampton, VA, USA
A open loop guidance architecture for navigationally robust on-orbit docking
Chern, Hung-Sheng; Aug 1, 1995; In English
Contract(s)/Grant(s): NCC1-104; RTOP 242-80-01-02
Report No.(s): NASA-CR-4687; NAS 1.26:4687; No Copyright; Avail: CASI; A05, Hardcopy

The development of an open-hop guidance architecture is outlined for autonomous rendezvous and docking (AR&D) missions to determine whether the Global Positioning System (GPS) can be used in place of optical sensors for relative initial position determination of the chase vehicle. Feasible command trajectories for one, two, and three impulse AR&D maneuvers are determined using constrained trajectory optimization. Early AR&D command trajectory results suggest that docking accuracies are most sensitive to vertical position errors at the initial conduction of the chase vehicle. Thus, a feasible command trajectory is based on maximizing the size of the locus of initial vertical positions for which a fixed sequence of impulses will translate the chase vehicle into the target while satisfying docking accuracy requirements. Documented accuracies are used to determine whether relative GPS can achieve the vertical position error requirements of the impulsive command trajectories. Preliminary development of a thruster management system for the Cargo Transfer Vehicle (CTV) based on optimal throttle settings is presented to complete the guidance architecture. Results show that a guidance architecture based on a two impulse maneuvers generated the best performance in terms of initial position error and total velocity change for the chase vehicle.
Author
Global Positioning System; Orbital Rendezvous; Spacecraft Docking; Spacecraft Guidance; Spacecraft Trajectories; Trajectory Optimization

19960006838 Houston Univ., TX, USA
Superconducting magnets for space applications
Weinstein, Roy; Aug 25, 1995; In English
Contract(s)/Grant(s): NAG9-743
Report No.(s): NASA-CR-199406; NAS 1.26:199406; No Copyright; Avail: CASI; A02, Hardcopy

The development of new materials used to make superconducting trapped field (permanent) magnets and a continuation of tests on a magnetic bumper/tether for spacecraft docking are reported. A new pinning center was developed by adding a small amount of U-235 to the superconductor. A maximum trapped field of 31,000 Gauss was attained using the uranium-seeded material. Work was continued on older (non-uranium) materials. Fields of 8.3 Tesla and 10.1 Tesla were successfully trapped. The trapped fields achieved by these magnets are now so high that under certain conditions the magnets will crack due to magnetic pressure, during activation. The soft docking device is based upon superconducting trapped field magnets and consists of an electromagnet mounted on the front of one spacecraft and an area of superconductor on the front of the other. As the two spacecraft approach, the superconductor is cooled in zero magnet field, and the electromagnet is turned on. An experimental apparatus was developed to measure the repulsive 'bumper' force which occurs as the two spacecraft near each other and the force which occurs after they magnetically 'bounce' off one another. There is a repulsive force upon approach; upon retreat there is first a repulsive force which, a small distance away, evolves into an attractive force. Because of this attractive force, the system can be designed or powered to achieve a large bumper force followed by automatic tethering. Extrapolating the results to a sizable bumper, it is found that bumper forces of well over 10 tons are achievable. Both single Y123 magnets and large matrices of small Y123 magnets were investigated. The original kinetic energy of the collision is almost entirely converted to magnetic energy. An hour after the collision, 15% of the initial kinetic energy is still trapped as magnetic field; the other 85% has been converted first to magnetic energy, and then to heat, at varying rates given by the 'creep' mechanism.

CASI

Permanent Magnets; Spacecraft Docking; Superconducting Magnets; Trapped Magnetic Fields; YBCO Superconductors

19960003897 Universidad Politecnica de Madrid, Madrid, Spain
Use of simulation tools and facilities for Rendez-Vous and Docking missions
Serrano-Martinez, J. B.; AGARD, Space Systems Design and Development Testing; Mar 1, 1995; In English; Copyright; Avail: CASI; A03, Hardcopy

This paper presents a methodology for the use of simulation tools and facilities for the different phases of a Rendezvous Docking (RVD) project. The methodology is developed trying to minimize development risks and planning shifts. Emphasis is placed on the elements which are unique on the RVD systems, namely, the Guidance, Navigation and Control subsystem, the on-board operations and the docking mechanism assembly. Such a methodology is based on the reuse of existing simulation tools and facilities in Europe. The Automatic Rendezvous Capture Demonstration Mission (ARC) is taken as example RVD project. The rationale of the proposed methodology presented including: the role of simulators during the different phases of the RVD project (namely, development, verification, execution, and post flight phases), the identification of simulation requirements derived from the foreseen application and the particularities of the RVD systems, the review of existing simulation tools and facilities in Europe and the analysis of their applicability for the ARC project including identification and analysis of the required upgrades and adaptations on the reused simulators and the required characteristics of the non-existing simulators.

Author

Airborne/Spaceborne Computers; Computerized Simulation; Simulators; Space Rendezvous; Spacecraft Docking; Unmanned Spacecraft

19960001496 Lockheed Engineering and Sciences Co., Houston, TX, USA
STS-63 Space Shuttle report
Fricke, Robert W., Jr.; Jun 1, 1995; In English
Report No.(s): NASA-CR-199572; NAS 1.26:199572; NSTS-08296; No Copyright; Avail: CASI; A04, Hardcopy

The STS-63 Space Shuttle Program Mission Report summarizes the Payload activities and provides detailed data on the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle Main Engine (SSME) systems performance during this sixty-seventh flight of the Space Shuttle Program, the forty-second since the return to flight, and twentieth flight of the Orbiter vehicle Discovery (OV-103). In addition to the OV-103 Orbiter vehicle, the flight vehicle consisted of an ET that was designated ET-68; three SSME's that were designated 2035, 2109, and 2029 in positions 1, 2, and 3, respectively; and two SRB's that were designated BI-070. The RSRM's that were an integral part of the

SRB's were designated 360Q042A for the left SRB and 360L042B for the right SRB. The STS-63 mission was planned as an 8-day duration mission with two contingency days available for weather avoidance or Orbiter contingency operations. The primary objectives of the STS-63 mission were to perform the Mir rendezvous operations, accomplish the Spacehab-3 experiments, and deploy and retrieve the Shuttle Pointed Autonomous Research Tool for Astronomy-204 (SPARTAN-204) payload. The secondary objectives were to perform the Cryogenic Systems Experiment (CSE)/Shuttle Glo-2 Experiment (GLO-2) Payload (CGP)/Orbital Debris Radar Calibration Spheres (ODERACS-2) (CGP/ODERACS-2) payload objectives, the Solid Surface Combustion Experiment (SSCE), and the Air Force Maui Optical Site Calibration Tests (AMOS). The objectives of the Mir rendezvous/flyby were to verify flight techniques, communication and navigation-aid sensor interfaces, and engineering analyses associated with Shuttle/Mir proximity operations in preparation for the STS-71 docking mission. Derived from text

Flyby Missions; Space Transportation System; Space Transportation System Flights; Spaceborne Experiments; Spacecraft Docking

19950057561

ROSETTA interplanetary and near comet navigation: A challenge for ground operations

Hechler, M.; Revista Brasileira de Ciencias Mecanicas; 1994; ISSN 0100-7386; In English; Copyright; Avail: Other Sources

The prime objective of the ROSETTA Comet Rendezvous Mission is in situ analysis of cometary matter. Launched by Ariane 5 in July 2003, the ROSETTA spacecraft will reach comet Schwassmann-Wachmann 3 in 2008 utilizing (powered) gravity assists at Mars and Earth and also passing by an asteroid. It will enter into orbits around the comet and observe the nucleus through its perihelion passage in 2011. ROSETTA mission operations will be performed by European Space Operations Centre (ESOC). A major task will be to navigate the spacecraft healthily and safely towards and near the comet. The navigation during the interplanetary cruise, the planetary and asteroid flybys and the comet approach will utilize conventional range and Doppler tracking and some ′classical' optical navigation, imaging the targets as point sources against the star background. Finally when the spacecraft is near the comet, imaging of landmarks on the surface of the cometary nucleus will provide the necessary spacecraft position and comet rotational state knowledge.

Author (Herner)

ESA spacecraft; Ground Support Systems; Rendezvous Guidance; Rendezvous Trajectories; Rosetta Mission; Schwassmann-Wachmann Comet; Space Navigation; Spacecraft Control

19950034166

Rendezvous and docking difficulties in the Soviet manned space programme

Harvey, Brian; British Interplanetary Society Journal; September 1994; ISSN 0007-094X; 47, 9; In English; Copyright; Avail: Other Sources

The Soviet space program suffered repeated difficulties in achieving orbital rendezvous and docking in its early years. This articles examines why, and the significance of these difficulties.

Author (Herner)

Manned Spacecraft; Space Rendezvous; Spacecraft Docking; Spacecraft Guidance

19950024351 Transition Research, Inc., Danbury, CT, USA

Log-polar binocular vision system

Weinman, Carl F. R.; Dec 1, 1994; In English

Contract(s)/Grant(s): NAS9-18637; SBIR-09.05-8988A

Report No.(s): NASA-CR-188375; NAS 1.26:188375; No Copyright; Avail: CASI; A05, Hardcopy

The objective of this research is to develop and implement new techniques for real time stereo vision for robots, based on active binocular vision using log-polar pixel layout and novel Gabor filter processing. The active vision platform is a high performance servo controlled binocular mount designed and built under this project. It emulates the articulation and speed of the human eye-head system. High performance processing is based on local Gabor filters embedded in global log-polar image plane geometry. This choice of geometry and processing, developed from first principles, closely resembles the structure and function of the primate retina and visual cortex. Binocular stereo vision is demonstrated on an autonomous mobile robot equipped with active binocular vision. Using real time visual guidance, the robot can perceive 3D environments and maneuver according to its perceptions. The new approach to vision relieves the computational bottlenecks of conventional machine vision, and provides robust sensory information which is well suited to real time maneuvering and manipulation. Space applications include eye-hand coordination for manipulators and high precision passive sensing for docking. Commercial

applications include 3D visual telepresence for remote inspection and repair in nuclear and hazardous environments, visual autopilot for autonomous vehicles, and real time vision for robot arms in unstructured manipulation environments. The latter includes semi-autonomous aides for the elderly and handicapped.
Author
Binocular Vision; Computer Vision; Real Time Operation; Robot Arms; Robotics; Robots; Stereoscopic Vision

19950022674 Stanford Univ., CA, USA
Experiments in cooperative manipulation of objects by free-flying robot teams
Dickson, William Charles; JAN 1, 1994; In English; No Copyright; Avail: Other Sources

This dissertation makes several contributions to the control of objects using a team of robots. To verify these contributions, laboratory experiments have demonstrated a team of free-flying robots capturing, transporting, and docking a large, freely moving object. In these experiments, the object and robots float on a thin cushion of air over a granite surface plate, simulating in two dimensions the drag-free, zero-gravity conditions of space. A human user commands the object location and orientation through a graphical user interface. The robots then capture and so position the object, with no additional input required from the user. On command, the robots dock the captured object with a second stationary object. This dissertation presents the AUTOMAN (AUtonomous robot Team Object MANipulation) hierarchy developed in this research as a framework for providing object-based task-level control of a system that uses a team of independently operating robots. The AUTOMAN hierarchy implements a carefully chosen set of interfaces between the various elements of the distributed-computation system that maximizes the autonomy of the robots -- under the constraint that the robots must provide cooperative control of a common object. A Decentralized Object-Impedance Controller was developed to allow a team of independently operating robots to work as a team to cooperatively manipulate a common object. The communication interface between a central coordinating processor and the robots is a low-bandwidth specification of a desired object trajectory and a programmable impedance relationship between the object's motion and external forces. Addressing the low-level control of the robots themselves, this dissertation presents the Hybrid-Dynamics controller that uses a novel control approach to assimilated both discrete-valued actuators (such as the on-off thrusters used by the experimental robots) and continuous valued actuators (such as motors) in system applications requiring precise control. The Subsystem-Merging dynamic modelling method has been developed for producing a system model directly from subsystem descriptions. This method takes advantage of simple kinematic relationships to merge subsystem descriptions into a full system model with no need for decomposing the subsystems. The resulting system model is expressed in terms of the subsystem descriptions; thus the model can be interpreted symbolically as well as numerically.
Dissert. Abstr.
Autonomy; Computerized Simulation; Environment Simulation; Manipulators; Remote Control; Robot Control; Robots; Task Planning (Robotics); Telerobotics; Weightlessness

19950020038 Naval Postgraduate School, Monterey, CA, USA
An analysis of orbital propagators for Low Earth Orbit Rendezvous
Pollock, Kenneth R.; Sep 1, 1994; In English
Report No.(s): AD-A288883; No Copyright; Avail: Defense Technical Information Center (DTIC); Limited Reproducibility: More than 20% of this doc

This thesis examines the performance of three different orbital propagators to determine which provide the best performance for use in Low Earth Orbit Rendezvous. The performance evaluation is based upon the propagator's accuracy and the amount of time required to produce a solution. A Cowell high-fidelity propagator is used as a base line for comparison with an Encke and Clohessy-Wiltshire propagator. To further enhance the examination a Jacchia-70 atmospheric model and a GEM-9 Geopotential model are used to provide perturbing acceleration inputs to the propagators. All comparisons are performed in a Local Vertical, Local Horizontal Reference Frame with the target spacecraft at the coordinate center. Tainting of the input data set by a prior processor make the findings suspect. Findings support the prediction that while the Cowell propagator is the most accurate it also takes the most time to achieve results. Also, the Clohessy-Wiltshire, while taking the least time is the most inaccurate. The Encke propagator deliveries the most balanced result.
DTIC
Low Earth Orbits; Performance Tests; Rendezvous Guidance; Rendezvous Trajectories; Space Navigation

19950017299 Hitachi Ltd., Kawasaki, Japan
Autonomous spacecraft executive and its application to rendezvous and docking
Komura, Fuminobu; Furuya, Masatoshi; Sasaki, Toshiro; Anderson, Robert L.; Tsugawa, Roy K.; JPL, Third International

Symposium on Artificial Intelligence, Robotics, and Automation for Space 1994; Oct 1, 1994; In English; No Copyright; Avail: CASI; A01, Hardcopy

Autonomy is needed for future spacecraft to solve the problems of human operator overload and transmission delay. This paper describes the autonomous spacecraft executive for rendezvous and docking. It is an onboard expert system and has decision making capability for mission planning of nominal and contingency cases. The executive has been developed and verified using a hardware motion based simulator.

Author

Autonomous Navigation; Expert Systems; Mission Planning; Orbital Rendezvous; Spacecraft Docking; Spacecraft Guidance

19950017291 Tokyo Inst. of Tech., Tokyo, Japan

Development of the dynamic motion simulator of 3D micro-gravity with a combined passive/active suspension system

Yoshida, Kazuya; Hirose, Shigeo; Ogawa, Tadashi; JPL, Third International Symposium on Artificial Intelligence, Robotics, and Automation for Space 1994; Oct 1, 1994; In English; No Copyright; Avail: CASI; A01, Hardcopy

The establishment of those in-orbit operations like 'Rendez-Vous/Docking' and 'Manipulator Berthing' with the assistance of robotics or autonomous control technology, is essential for the near future space programs. In order to study the control methods, develop the flight models, and verify how the system works, we need a tool or a testbed which enables us to simulate mechanically the micro-gravity environment. There have been many attempts to develop the micro-gravity testbeds, but once the simulation goes into the docking and berthing operation that involves mechanical contacts among multi bodies, the requirement becomes critical. A group at the Tokyo Institute of Technology has proposed a method that can simulate the 3D micro-gravity producing a smooth response to the impact phenomena with relatively simple apparatus. Recently the group carried out basic experiments successfully using a prototype hardware model of the testbed. This paper will present our idea of the 3D micro-gravity simulator and report the results of our initial experiments.

Derived from text

Manipulators; Microgravity; Motion Simulators; Suspending (Hanging); Test Stands; Three Dimensional Models

19950011379 Bulgarian Academy of Sciences, Sofia, Bulgaria

Space greenhouse SVET as a part of a future life support system

Ivanova, T. N.; Sapunova, S. M.; ESA, Proceedings of the Fifth European Symposium on Life Sciences Research in Space; Aug 1, 1994; In English; Copyright; Avail: CASI; A02, Hardcopy; US Distribution and Sales Only

SVET, a small dimension (0.1 sq m vegetation area) space greenhouse of a new generation, is operating completely automatically and controlling the environmental conditions for higher plant growth. The SVET space greenhouse was mounted on the CRISTAL technological module, docked to the Mir orbital space station on 10 Jun. 1990. The Soviet cosmonauts Balandin and Solovyov started the first experiments by sowing seeds of radish and cabbage vegetables considered as one of the important crops for a future biological life support system in space. The complex systems of sensors, amplifiers, microcomputer, light, ventilation, moistening, and aeration ensured the germination and growing of the plants in the conditions of microgravity. The results of the first two-months' experiments are satisfactory; the plants are too small sized but normally developed. For the first time the root crops of radish plants are produced onboard.

ESA

Closed Ecological Systems; Environmental Control; Food Production (In Space); Greenhouses; Phytotrons

19950010837 European Space Agency. European Space Operations Center, Darmstadt, Germany

EURECA mission control experience and messages for the future

Huebner, H.; Ferri, P.; Wimmer, W.; NASA. Goddard Space Flight Center, Third International Symposium on Space Mission Operations and Ground Data Systems, Part 1; Nov 1, 1994; In English; No Copyright; Avail: CASI; A02, Hardcopy

EURECA is a retrievable space platform which can perform multi-disciplinary scientific and technological experiments in a Low Earth Orbit for a typical mission duration of six to twelve months. It is deployed and retrieved by the NASA Space Shuttle and is designed to support up to five flights. The first mission started at the end of July 1992 and was successfully completed with the retrieval in June 1993. The operations concept and the ground segment for the first EURECA mission are briefly introduced. The experiences in the preparation and the conduction of the mission from the flight control team point of view are described.

Author

Deployment; Earth Orbital Rendezvous; Eureca (ESA); Flight Control; Ground Based Control; Integrated Mission Control Center; Mission Planning

19950008237 Alabama Univ., Huntsville, AL, USA

Neural networks: Alternatives to conventional techniques for automatic docking

Vinz, Bradley L.; Huntsville Association of Technical Societies, TABES 1994: 10th Annual Technical and Business Exhibition and Symposium; JAN 1, 1994; In English

Contract(s)/Grant(s): NGT-50679

Report No.(s): TABES PAPER 94-627; No Copyright; Avail: CASI; A02, Hardcopy

Automatic docking of orbiting spacecraft is a crucial operation involving the identification of vehicle orientation as well as complex approach dynamics. The chaser spacecraft must be able to recognize the target spacecraft within a scene and achieve accurate closing maneuvers. In a video-based system, a target scene must be captured and transformed into a pattern of pixels. Successful recognition lies in the interpretation of this pattern. Due to their powerful pattern recognition capabilities, artificial neural networks offer a potential role in interpretation and automatic docking processes. Neural networks can reduce the computational time required by existing image processing and control software. In addition, neural networks are capable of recognizing and adapting to changes in their dynamic environment, enabling enhanced performance, redundancy, and fault tolerance. Most neural networks are robust to failure, capable of continued operation with a slight degradation in performance after minor failures. This paper discusses the particular automatic docking tasks neural networks can perform as viable alternatives to conventional techniques.

Author (revised)

Attitude Control; Compression Ratio; Data Compression; Digital Data; Edge Detection; Image Processing; Maneuvers; Neural Nets; Orbital Rendezvous; Orientation; Pattern Recognition; Rendezvous Guidance; Spacecraft Docking; Target Recognition

19950007418 ISRO Satellite Centre, Peenya, Bangalore, India

A vision based attitude and position estimation algorithm for rendezvous and docking

Mukundan, R.; Narayanan, R. V. Raghu; Philip, N. K.; Journal of Spacecraft Technology, Volume 4, No. 2, July 1994; Jul 1, 1994; In English; No Copyright; Avail: CASI; A02, Hardcopy

This paper presents an algorithm for estimating the attitude and position parameters of an object from its image using point correspondence information. The attitude of the object is defined in terms of quarternion elements and is related to the measured image coordinates of three feature points through a system of non-linear equations. A closed-form solution of this system is derived for the direct estimation of the quarternion parameters as well as the position vector components. The algorithm finds application in the development of computer vision-based autonomous guidance schemes for the final approach phase of a rendezvous and docking mission.

Author

Algorithms; Attitude (Inclination); Attitude Control; Image Processing; Nonlinearity; Orbital Rendezvous; Rendezvous Guidance; Spacecraft Docking; Visual Discrimination

19940032995 George Washington Univ., Hampton, VA, USA

Evaluation of GPS position and attitude determination for automated rendezvous and docking missions

Diprinzio, Marc D.; Tolson, Robert H.; Jul 1, 1994; In English

Contract(s)/Grant(s): NCC1-104; RTOP 225-99-00-01

Report No.(s): NASA-CR-4614; NAS 1.26:4614; No Copyright; Avail: CASI; A05, Hardcopy

The use of the Global Positioning System for position and attitude determination is evaluated for an automated rendezvous and docking mission. The typical mission scenario involves the chaser docking with the target for resupply or repair purposes, and is divided into three sections. During the homing phase, the chaser utilizes coarse acquisition pseudorange data to approach the target; guidance laws for this stage are investigated. In the second phase, differential carrier phase positioning is utilized. The chaser must maintain a quasiconstant distance from the target, in order to resolve the initial integer ambiguities. Once the ambiguities are determined, the terminal phase is entered, and the rendezvous is completed with continuous carrier phase tracking. Attitude knowledge is maintained in all phases through the use of the carrier phase observable. A Kalman filter is utilized to estimate all states from the noisy measurement data. The effects of selective availability and cycle slips are also investigated.

Author (revised)

Command Guidance; Global Positioning System; Midcourse Guidance; Orbital Rendezvous; Rendezvous Guidance; Space Navigation; Spacecraft Docking; Spacecraft Guidance; Terminal Guidance

19940032318 NASA Marshall Space Flight Center, Huntsville, AL, USA

Global Positioning System Synchronized Active Light Autonomous Docking System

Howard, Richard, inventor, et al.; Aug 1, 1994; In English; US-PATENT-APPL-SN-283728; NASA-CASE-MFS-28853-1

Report No.(s): NAS 1.71:MFS-28853-1; No Copyright; Avail: CASI; A03, Hardcopy

A Global Positioning System Synchronized Active Light Autonomous Docking System (GPSSALADS) for automatically docking a chase vehicle with a target vehicle comprises at least one active light emitting target which is operatively attached to the target vehicle. The target includes a three-dimensional array of concomitantly flashing lights which flash at a controlled common frequency. The GPSSALADS further comprises a visual tracking sensor operatively attached to the chase vehicle for detecting and tracking the target vehicle. Its performance is synchronized with the flash frequency of the lights by a synchronization means which is comprised of first and second internal clocks operatively connected to the active light target and visual tracking sensor, respectively, for providing timing control signals thereto, respectively. The synchronization means further includes first and second Global Positioning System receivers operatively connected to the first and second internal clocks, respectively, for repeatedly providing simultaneous synchronization pulses to the internal clocks, respectively. In addition, the GPSSALADS includes a docking process controller means which is operatively attached to the chase vehicle and is responsive to the visual tracking sensor for producing commands for the guidance and propulsion system of the chase vehicle.

NASA

Autonomous Navigation; Global Positioning System; Guidance Sensors; Optical Tracking; Rendezvous Guidance; Spacecraft Docking; Spacecraft Guidance; Tracking (Position)

19940028609 Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, USA

Identification and control of structures in space

Meirovitch, Leonard; May 19, 1994; In English

Contract(s)/Grant(s): NAG1-225

Report No.(s): NASA-CR-195910; NAS 1.26:195910; No Copyright; Avail: CASI; A05, Hardcopy

During the last phase of the project, emphasis has changed to flexible space robotics, by mutual agreement between Dr. R. C. Montgomery, NASA Technical Officer, and the Principal Investigator. Significant advances have been achieved over the period covered by this report. Research has been concerned with two main subjects: (1) the maneuvering and control of freely floating flexible space robots, and (2) the development of a theory for the motion of flexible multibody systems. Work on the first subject has resulted in two papers, both of them concerned with planar maneuvers. The first is concerned with the maneuvering and delivery of a payload to a certain point and in a certain orientation in space. The second is concerned with the docking maneuver with a target whose motion is not known a priori. Both papers will appear in the 'Journal of Guidance, Control, and Dynamics.' The second subject is concerned with the development of hybrid (ordinary and partial) differential equations for the three dimensional motion of flexible multibody systems, a subject of vital interest in flexible space robotics. The paper will appear in the 'Journal of Guidance, Control and Dynamics' in an issue dedicated to the memory of Lawrence W. Taylor, Jr. Abstracts and copies of the papers are hereby included.

Author

Equations of Motion; Flexible Bodies; Robot Control; Robot Dynamics; Robotics; Robots; Three Dimensional Motion

19940027915 NASA Ames Research Center, Moffett Field, CA, USA

Refining fuzzy logic controllers with machine learning

Berenji, Hamid R.; NASA, Washington, Technology 2003: The Fourth National Technology Transfer Conference and Exposition, Volume 2; Feb 1, 1994; In English; No Copyright; Avail: CASI; A01, Hardcopy

In this paper, we describe the GARIC (Generalized Approximate Reasoning-Based Intelligent Control) architecture, which learns from its past performance and modifies the labels in the fuzzy rules to improve performance. It uses fuzzy reinforcement learning which is a hybrid method of fuzzy logic and reinforcement learning. This technology can simplify and automate the application of fuzzy logic control to a variety of systems. GARIC has been applied in simulation studies of the Space Shuttle rendezvous and docking experiments. It has the potential of being applied in other aerospace systems as well as in consumer products such as appliances, cameras, and cars.

Author

Controllers; Fuzzy Systems; Machine Learning

19940027882 Draper (Charles Stark) Lab., Inc., Cambridge, MA, USA

A six degree of freedom, plume-fuel optimal trajectory planner for spacecraft proximity operations using an A* node search

Jackson, Mark Charles; May 1, 1994; In English

Contract(s)/Grant(s): NAS9-18426

Report No.(s): NASA-CR-188285; NAS 1.26:188285; CSDL-T-1221; Copyright; Avail: CASI; A07, Hardcopy

Spacecraft proximity operations are complicated by the fact that exhaust plume impingement from the reaction control jets of space vehicles can cause structural damage, contamination of sensitive arrays and instruments, or attitude misalignment during docking. The occurrence and effect of jet plume impingement can be reduced by planning approach trajectories with plume effects considered. An A* node search is used to find plume-fuel optimal trajectories through a discretized six dimensional attitude-translation space. A plume cost function which approximates jet plume isopressure envelopes is presented. The function is then applied to find relative costs for predictable 'trajectory altering' firings and unpredictable 'deadbanding' firings. Trajectory altering firings are calculated by running the spacecraft jet selection algorithm and summing the cost contribution from each jet fired. A 'deadbanding effects' function is defined and integrated to determine the potential for deadbanding impingement along candidate trajectories. Plume costs are weighed against fuel costs in finding the optimal solution. A* convergence speed is improved by solving approach trajectory problems in reverse time. Results are obtained on a high fidelity space shuttle/space station simulation. Trajectory following is accomplished by a six degree of freedom autopilot. Trajectories planned with, and without, plume costs are compared in terms of force applied to the target structure. Author (revised)

Jet Impingement; Rendezvous Trajectories; Rocket Exhaust; Space Rendezvous; Spacecraft Docking; Spacecraft Trajectories; Thrust Control; Trajectory Planning

19940003089

OOS 1.0 - Orbital Operations Simulator Version 1.0 With Prepare Processor and User Interface Shell

Edwards, C.; Jan 1, 1994; In English

Report No.(s): MSC-21615; No Copyright; Avail: Other Sources; Program $1,800.00

The OOS (Orbital Operations Simulator) was developed to model complex space vehicular systems and be a 'testbed' for new flight software. This simulator has a multi-vehicular capability to model on-orbit proximity and docking operations. Version 1.0, with its Prepare Processor and User Interface Shell (UI), was designed to be a true multi-vehicle dynamic simulator with the capability to easily change the math models of spacecraft subsystems. An OOS simulation application is defined by a set of model configuration files. Each model configuration file contains specifications for source code modules and data sets which define a single vehicle or environment in which the vehicle 'flys.' The source code module library include dynamics, effector, sensor, flight software, and environment modules. Dynamics and kinematics modules calculate dynamic forces and torques due to environment interactions, effectors, slosh effects, plume effects, body flex effects, etc., and propagate the state of the vehicle. Effector modules model types of hardware which provide active control for the vehicle, such as jets, control moment gyros, and reel motor drives. Sensor modules model the radar, rate gyros, and other sensing hardware of the vehicle. Flight software provides the vehicle's guidance, navigation and control for automated flight, and uses the output from the sensors to determine the control commands issued to the sensors. Device interfaces in these modules provide the capability to use hand controllers for input, graphics monitors for visual feedback, and personal computers for simulation control. Environment modules are generalized for given planets such as Earth or Mars, and define atmospheric density profiles, planetary gravitational fields, etc. The OOS testbed execution data file Prepare Processor provides the OOS user with 'programmable' data file capabilities via lexical interpretation of the data file contents. The Prepare Processor has the capability to interpret several forms of data file entries, including mathematical operations and subroutine calls. It checks all run data file inputs for consistency and compatibility and also checks the syntax and variable attributes for the entire execution data file. The OOS User Interface Shell 'surrounds' the entire OOS system. It provides an interface between the OOS user and the UNIX operating system by utilizing the system's Bourne Shells to provide simple commands for complex operations. The UI operates three major areas of the OOS Testbed System: Simulation Application Assembly, Application Operation, and Application data postprocessing. During Application Assembly, the OOS user simply specifies which vehicle to simulate and the environment in which these vehicles 'fly'. The UI performs several complex tasks to assemble the user's application based on the input. The UI automatically generates application executive source code to incorporate all software modules specified in the application definition file. The UI then compiles the new executive source code, links the new object code to the OOS testbed object library and creates data bases unique to the user's application. The UI utilizes high level OOS testbed databases which define software module interfaces and vehicle model definitions. Version 1.0 of the Orbital Operations Simulator was developed on a Sun workstation in 1987, and replaces the previous version which was developed in 1984 (MSC-20941). The

program is written in K & R standard C, LEX, and YACC languages and operates under a System V shell. The memory requirement for the program is approximately 180KB RAM. OOS 1.0 is distributed on four PC/MS DOS format diskettes. COSMIC

Interfaces; OOS 1.0; Orbital Maneuvers; Space Shuttles; Space Simulators

19940000100 NASA Marshall Space Flight Center, Huntsville, AL, USA

Synchronized Flashing Lights For Approach And Docking

Book, Michael L.; Howard, Richard T.; Bryan, Thomas C.; Bell, Joseph L.; Laser Tech. Brief.; Feb 1, 1994; 2, 1; In English Report No.(s): MFS-28853; No Copyright; Additional information available through: National Technology Transfer Center (NTTC), Wheeling, WV 26003, (Tel: 1-800-678-6882).

Proposed optoelectronic system for guiding vehicle in approaching and docking with another vehicle includes active optical targets (flashing lights) on approached vehicle synchronized with sensor and image-processing circuitry on approaching vehicle. Conceived for use in automated approach and docking of two spacecraft. Also applicable on Earth to manually controlled and automated approach and docking of land vehicles, aircraft, boats, and submersible vehicles, using GPS or terrestrial broadcast time signals for synchronization. Principal advantage: optical power reduced, with consequent enhancement of safety.

Approach; Optoelectronic Devices; Spacecraft Docking

Subject Terms

Corporate Sources

Document Authors