A89-48063 The problem of constructing three-dimensional gyrodyne systems (Problema postroeniia prostranstvennykh girodinnykh sistem). E. N. TOKAR', *Kosmicheskie Issledovaniia* (ISSN 0023-4206), Vol. 27, May–June 1989, pp. 368–374. 8 Refs.

Four problems associated with the construction of three-dimensional and multiple three-dimensional gyrodyne systems are formulated. It is shown that the solution to these problems is reduced to the search for infinite series of polyhedrons satisfying certain extreme requirements.

A89-40572 Construction of an algorithm for taking into accountatmospheric drag when investigating the motion of an artificial earth satellite (Postroenie algoritma ucheta soprotivleniia atmosfery v dvizhenii iskusstvennogo sputnika zemli). E. P. STREZHENKOVA and V. A. TAMAROV, *Astronomicheskii Zhurnal* (ISSN 0004-6299), Vol. 66, Mar.–Apr. 1989, pp. 404–411. 12 Refs.

An analytical theory for taking into account perturbations due to atmospheric drag in investigations of satellite motion is developed. The theory is based on an asymmetric variant of the Euler intermediate orbit. The expansion of components of perturbing acceleration due to the drag of a satellite in a stationary rotating atmosphere is presented.

A89-37360 A decomposition method applied in the problem of near-planetary astronavigation using pseudostars (Metod dekompozitsii v zadache priplanetnoi astronavigatsii s ispol'zovaniem psevdozvezd). V. F. PETRISHCHEV, *Kosmicheskie Issledovaniia* (ISSN 0023-4206), Vol. 27, Mar.–Apr. 1989, pp. 221–227.

The paper examines the problem of measurement-space decomposition in the problem of near-planetary astronavigation including the zenith distances of two stars and the angular diameter of the planet. Particular attention is given to the decomposition of the state space into a four-dimensional space of in-plane motion parameters and a two-dimensional subspace of out-of-plane motion parameters. From measurements of the zenith distances of two sighted stars, there is a transition to the zenith distances of two pseudostars, the direction to the first of which coincides with thecurrent transversal, while the direction to the second coincides with a binormal to the plane of the a priori orbit. The in-plane parameters are determined from measurements of the zenith distance of the first pseudostarand the angular diameter of the planet, while the out-of-plane parameters are determined from measurements of the zenith distance of the second pseudostar.

A89-18436 Dynamics of a spacecraft with direct active control of the gravity gradient stabilizer (Dinamika kosmicheskogo apparata s priamym aktivnym upravleniem gravitatsionnym stabilizatorom). E. M. POTAPENKO, *Kosmicheskie Issledovaniia* (ISSN 0023-4206), Vol. 26, Sept.–Oct. 1988, pp. 699–708. 8 Refs.

Equations of spacecraft motion are obtained with allowance for an arbitrary but finite number of tons of elastic oscillations of a controlled gravity gradient stabilizer. A dynamic controller is used to optimize the spacecraft attitude control and stabilization system with allowancefor the first tone of the elastic oscillations.

A89-42470 Determination of the precision of the orientation and stabilization system of the direct telecommunication satellite Ekran from flight test results and possible ways of its improvement (Opredelenie tochnosti sistemy orientatsii i stabilizatsii sputnika neposredstvennogo televeshchaniia 'Ekran' po rezul'tatam letnykh ispytanii i vozmozhnye puti ee povysheniia). S. N. KALINOVICH, L. A. MIROSHNICHENKO, G. M. MARKELOV, and V. A. RAEVSKII, V. A. *Pioneers of space and the present age* (A89-42451 18-99). Moscow, Izdatel'stvo Nauka, 1988, pp. 138–145.

An analytical procedure for estimating the precision of the orientation and stabilization system of the Ekran telecommunication satellite on the basis of flight test data is presented, and recommendations are given as to how to improve the precision of the system. These include: (1) consideration of the constant component of the methodological error when installing the local vertical plotter on the ground; (2) introduction of constant corrections into the bank control circuit; and (3) improving the precision of orientation with respect to yaw by reducing the pumping angle of the gyro flywheel axis once the methodological error has been compensated.

A89-35552 A gradiometric inertial navigation system. II (Gradientometricheskaia inertsial'naia navigatsionnaia sistema. II). IU. A. KOROTAEV and V. IU. KLIUEV, *Priborostroenie* (ISSN 0021-3454), Vol. 32, Feb. 1989, pp. 26–31.

Different representations of the error equations for a three-component gradiometric inertial navigation system are obtained. Analytical solutions to these equations are obtained, and the effect of instrument errors on the accuracy of the system is evaluated.

A89-30078 Theory of semianalytical inertial damped structures invariant to external data errors (K teorii poluanaliticheskikh inertsial'nykh dempfirovannykh sistem, invariantnykh k pogreshnostiam vneshnei informatsii). R. M. KUKULIEV, *Priborostroenie* (ISSN 0021-3454), Vol. 32, Jan. 1989, pp. 40–45. 5 Refs.

An inertial navigation system is considered which uses external data signals for system damping. Theorems are proved concerning the impossibility of attaining absolute invariance of the error of gyroplatform deviation from the reference vertical to the external data errors.

A89-13241 Mathematical modeling of an inertial navigation system in an anomalous gravitational field (Matematicheskoe modelirovanie raboty inertsial'noi navigatsionnoi sistemy v anomal'nom gravitatsionnom pole). IU. K. ZHBANOV, D. M. KLIMOV, and M. A. URIUPIN, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Tverdogo Tela* (ISSN 0572-3299), July–Aug. 1988, pp. 13–16. 6 Refs.

The operation of an ideal nonautonomous undamped inertial navigation system in a gravitational field is investigated by the method of direct mathematical modeling. A method for improving navigational precision is proposed which employs a bank of gradiometers for monitoring thecurrent values of the matrix of second derivatives of the anomalous geopotential. The effect of gradiometer errors on the precision of navigation is discussed.

Japanese Aerospace Literature
This month: *Spacecraft Navigation and Control*

A90-39331 Adaptive control of large space structures. YUZO SHIMADA, *Chinese Society of Astronautics Journal* (ISSN 1000-1328), No. 1, 1990, pp. 45–53. 5 Refs.

This paper deals with the application of a model reference adaptive control theory to the attitude control of large space structures that don't satisfy the conditions of sensor/actuator collocation. The signals from several different positions on the flexible appendages are combined into outputs so that the number of outputs and inputs is the same. As an example, a spacecraft that has flexible solar paddles and a momentum wheel within the rigid central body is studied. Computer simulation results are presented for a situation where the flexural rigidity of the flexible appendages are assumed to vary widely from nominal values.

A90-30544 Observation of the Z mode with DE 1 and its analysis by three-dimensional ray tracing. KOZO HASHIMOTO and WYNNE CALVERT, *Journal of Geophysical Research* (ISSN 0148-0227), Vol. 95, April 1, 1990, pp. 3933–3942. 27 Refs. (NAG5-310; NAGW-1206).

Certain Z-mode wave emissions in the earth's magnetosphere have been identified using the wave spectra and polarization measurements of the DE 1 satellite. Although such emissions accompany the aurora, and thus presumably originate from the evening-sector auroral zone, they are found to occur over much wider ranges of latitude and longitude. Since the predicted cyclotron maser emission at the cyclotron frequency could not have produced waves which travel such great distances, as shown by three-dimensional ray tracing, it is proposed instead that these emissions must originate from lower altitudes within the auroral zone and probably from near the plasma frequency inside the auroral plasma cavity.

A90-13493 Manipulator control algorithm to minimize the effect of arm movement on the spacecraft attitude and translational motion. Y. OHKAMI, O. OKAMOTO, I. YAMAGUCHI, and T. KIDA, IAF 40th International Astronautical Congress, Malaga, Spain, Oct. 7-13, 1989. 7 p. (IAF Paper 89-377).

This paper presents a new algorithm for manipulator control to minimize the effect of the arm motion on the spacecraft attitude and translational motion. The method is based on the unified matrix approach, and also on the introduction of a 'virtual' hinge that restricts the spacecraft motion to a desired motion. This algorithm can be applied not only to digital simulation of the system in order to evaluate the controller performance or actuator gains but also to generation of the real time control law. Some numerical results are shown for illustration as applied to the spacecraft consisting of a main body and 4 arm manipulator.

A90-11725 Real-time relative motion monitoring for co-located geostationary satellites. SEIICHIROU KAWASE, *Communications Research Laboratory Journal* (ISSN 0914-9260), Vol. 36, July 1989, pp. 125–135. 5 Refs.

For the tracking of the relative orbital motion of two satellites closely placed and operated in the geostationary orbit, the concept of differential angle observation from a ground station is presented. A linearized Kalman filter is employed for the estimation of three-dimensional relative position and velocity, with the solar radiation pressure perturbation being analytically taken into account. A tracking simulation using pseudo-differential angle data indicates that an accuracy of a few hundreds of meters can be expected in the estimation of the relative position of the satellites.

A90-44160 Research and development of precision earth sensor. YASUFUMI WAKABAYASHI, HIROYUKI NAKAMURA, SHUNSUKE TANAKA, FUMIHO TAKAHASHI, TOSHIHIRO KURII et al., *Infrared technology XV; Proceedings of the Meeting,* San Diego, CA, Aug. 7–9, 1989 (A90-44129 19-35). Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, pp. 299–308. 5 Refs.

A precision horizon-crossing indicator for synchronous orbit (PHIS) suitable for the attitude control of a three-axis-stabilized satellite operating at transfer and geosynchronous altitude is considered. The principle of measurement, sensor configuration, functional block diagram, and sensor design features are outlined, and evaluation tests including performance, environmental, interface, and reliability measurements are described. A low-power (4-W) PHIS breadboard model weighting 1.9 kg is shown to achieve accuracy of + or − 0.003 deg in measurements of the pitch and roll attitude angles.

A90-23675 Characteristic multiplier assignment in continuous-time linear periodic systems. K. YOSHII and K. HAKOMORI, *International Journal of Control* (ISSN 0020-7179), Vol. 50, Dec. 1989, pp. 2349–2363. 22 Refs.

A characteristic multiplier assignment problem for continuous-time periodic systems with analytic coefficients is considered. First, the necessary and sufficient condition for controllability is shown. Under this condition, an algorithm for assigning a set of characteristic multipliers is proposed. The algorithm is constructed by a simple repetitive procedure, and is suited to computer programming. The given feedback gain matrix is composed of a sequence of Dirac delta functions; such a feedback system can easily be implemented using proper approximation to the delta function. Lastly, the design method is applied to the attitude control problem of a spin-stabilized satellite, and some simulation results are given.

A90-16524 Attitude stability of a flexible asymmetric dual spin spacecraft. KAZUO TSUCHIYA, KATSUHIKO YAMADA, and BRIJ N. AGRAWAL, *Dynamics of controlled mechanical systems; Proceedings of the IUTAM/IFAC Symposium,* Zurich, Switzerland, May 30–June 3, 1988 (A90-16516 04-31). Berlin and New York, Springer-Verlag, 1989, pp. 207–217. Research sponsored by INTELSAT.

The stability of the attitude motion of a large dual-spin spacecraft is studied, and the effects of various kinds of asymmetries of the spacecraft and energy dissipations in the spacecraft are examined. Attitude instabilities due to interactions between the asymmetries and the interactions between the asymmetries and the energy dissipations are examined in detail. The analysis is based on the method of multiple time scales. The results ae verified by numerical solutions based on Floquet's theorem.

A90-11874 Application of optimal control to initial alignment of strapdown Inertial Navigation System (INS). WEI PING LIU and MINORU HIGASHIGUCHI, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 32, Aug. 1989, pp. 67–78. 19 Refs.

Disturbance-rejected initial alignment of strapdown INS with optimal response is developed. In this method, the residual attitude angles can be obtained accurately and rapidly for a low-price less-accurate strapdown INS. In this approach, not only the optimal response is maintained in the alignment system, but also the random errors of inertial sensors and external influences are rejected in the alignment process. The computation of the alignment controller by this method is much simpler than that of the optimal estimation and control method. Since there is no need to do the on-line calculation for controller and filter during the alignment process, the load is low by comparison with that of the optimal estimation and control method.

A89-42808 Resolved motion rate control of space manipulators with generalized Jacobian matrix. YOJI UMETANI and KAZUYA YOSHIDA, *IEEE Transactions on Robotics and Automation* (ISSN 1042-296X), Vol. 5, June 1989, pp. 303–314. 15 Refs.

The authors establish a control method for space manipulators taking dynamical interaction between the manipulator arm and the base satellite into account. The kinematics of free-flying multibody systems is investigated by introducing the momentum conservation law into the formulation and a novel Jacobian matrix in generalized form for space robotic arms is derived. The authors develop a control method for space manipulators based on the resolved motion control concept. The proposed method is widely applicable in solving not only free-flying manipulation problems but also attitude-control problems. The validity of the method is demonstrated by computer simulations with a realistic model ofa robot satellite.

A89-38214 Adaptive control of large space structures. YUZO SHIMADA, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1371–1376. 5 Refs.

This paper deals with the application of a model reference adaptive control theory to the attitude control of large space structuresthat do not satisfy the conditions of sensor/actuator collocation. Signals from several different positions on flexible appendages are combined into outputs so that the number of outputs is the same as the number ofinputs. As an example, a spacecraft is considered that has flexible solarpaddles and a momentum wheel within the rigid central body.

A89-49041 Pyroelectric infrared detector for precision earth sensor. KUNIO NAKAMURA, TAKEO ISHIGAKI, AKIRA KANEKO, SHOZO TAKAHASHI, JUN NISHIDA et al., *International Journal of Infrared and Millimeter Waves* (ISSN 0195-9271), Vol. 10, Aug. 1989, pp. 907–930. 9 Refs.

Two IR detectors, developed for the precision earth sensor of the three-axis stabilized satellite ETS-VI, are reported. The detectors have a pair of IR sensing element, each of which is composed of a pyroelectric material (a flake of lead titanate ceramic for the A type and a sputtered epitaxial film of calcium-modified lead titanate for the B-type) and is mounted on an immersion lens. At 120 Hz, the detectivity of the A-type detector is 2.5 times as high as that of the previous model in the ETS-V and that of the B-type is 4.5 times as high. Random errors of 0.03 deg for the earth sensor with the A-type detector and 0.012 for the earth sensor with the B-type detector are found.

A89-43377 Effects of atmospheric density gradient on the stability and control of tethered subsatellite. NAOYUKI WATANABE and JUNJIRO ONODA, *Space tethers for science in the space station era; Proceedings of the Second International Conference,* Venice, Italy, Oct. 4–8, 1987 (A89-43326 18-12). Bologna, Societa Italiana di Fisica, 1988, pp. 424–432. 7 Refs.

The effects of an atmospheric density gradient on an in-plane swinging motion of a tethered subsatellite deployed in a circular low-altitude orbit are investigated in the case of station keeping, based on a simple mathematical model. It is shown analytically that the stability of the uncontrolled system is dominated by the value of the atmosphericdensity gradient. Moreover, the system with tension control of the tether is investigated, and the control law is optimized by means of the linear quadratic regulator (LQR) theory. The design of the control lawwithout considering the effects of the atmospheric density gradient leads to an unstable motion under the real atmosphere, and the stable region of the control gains are drastically limited by its effects. Therefore, it is concluded that considering the effects of the atmospheric density gradient is indispensable to the design of the tethered subsatellite system deployed in a low-altitude orbit.

A89-38251 A study on the requirements of the manipulator on the spacecraft considering its attitude control. MASANORI HOMMA and YASUHARU TAKASU, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 2 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1649–1654.

Simulation studies of a three-link manipulator ona three-axis-stabilized spacecraft were performed, with application to such in-orbit functions as part replacement, refueling, and berthing. The actuator torque requirements have been determined for various payload masses under zero-gravity conditions. Special attention is given to the need for control systems in the orbital transfer vehicle and the accuracy of the trajectory of the manipulator in inertial space.

A89-38219 Flight alignment of strapdown INS and its design by LQG optimal control of polynomial system approach. MINORU HIGASHIGUCHI and WEI PING LIU, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1401–1407.

Consideration is given to the alignment of a strapdown tangent-plane INS with respect to a local-level navigation system. The measured velocity of both systems are matched using the linear-quadratic Gaussianoptimal control method of the polynomical system approach (Grimble, 1986). Attitude and velocity error propagation equations and attitude and velocity matching equations are presented. Results are presented from simulations demonstrating the technique.

A89-38217 Application of the mission function control to deployment/retrieval of a subsatellite. HIRONORI FUJI, KENJI UCHIYAMA, and KENTAROH KOKUBUN, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1389–1394.

A mission function control algorithm is applied to control the deployment and retrieval of a subsatellite connected to a main body through the tether. A dynamical model is treated taking into account the three-dimensional librational motion and aerodynamic drag in the atmosphere. Results of numerical simulation show an excellent controlled behavior of the system approaching a specified desirable state.

A89-38185 Attitude and orbit control subsystem for ERS-1. TAKASHI SUZUKI, YOSHIHIRO HARADA, AKIHIRO NAKASHIMA, NAOYUKI NATORI, TOHRU OKANUMA et al., *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1187–1192.

The attitude and orbit control subsystem developed for the Earth Resources Satellite 1 is examined. The hardware, software, operational mode, and failure detection and recovery aspects of the subsystem are described. The functions of the subsystem are discussed, includinginitial attitude acquisition, orbit control, normal attitude control for earth observation, solar paddle drive, and failure detection and reconfiguration. The configuration of the system is illustrated and diagrams of operation in the acquisition and normal modes are presented.

A89-42786 Development of GPS positioning system 'PRESTAR'. YUJI SUGIMOTO, NORIYUKI KURIHARA, HITOSHI KIUCHI, AKIHIRO KANEKO, FUMITAKE SAWADA et al., *IEEE Transactions on Instrumentation and Measurement* (ISSN 0018-9456), Vol. 38, April 1989, pp. 644–647. 9 Refs.

A precise relative positioning system using GPS, called PRESTAR, has been developed and is designed to give accurate relative position measurements, precise time synchronization, and precise orbit determinations. PRESTAR uses a high-gain beam antenna to obtain highly accurate range datathrough the high signal-to-noise (S/N) ratio of the received signal. It makes use of a beam antenna, necessitating a single channel sequential system. Its performance gives accurate relative position measurements, precise time synchronization, and precise orbit determinations have been demonstrated with a 55-km baseline experiment. Longer baseline positioning experiments and orbit determination experiments are being planned. The authorsoutline the PRESTAR system and some results of experiments.

A89-38203 Navigation, guidance and control subsystem of Space Flyer Unit. TOSHIMITSU NISHIMURA, YOSHIOKI KUBO, and TETSUO YAMAGUCHI, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1299–1304.

The Space Flyer Unit (SFU), a small retrievable, reusable space platform, is reviewed, focusing on the development of the SFU navigation, guidance and control subsystem. The SFU configuration and operational sequence are described, and the requirements of the navigation, guidance, andcontrol subsystem are listed. The subsystem components are discussed, including the Inertial Measurement Unit, the acquisition sun sensor, the pointing sun sensor, the GPS reciever, the reaction wheel and wheel drive,and the magnetic torquer. The operation of SFU in earth-pointing, sun-pointing, and orbit control modes is examined. Also, consideration is given to the control modes, disturbance torques, stabilization of flexible solararrays, and rendezvous strategy.

A89-38202 GPS-INS-STAR—A navigation system for the era of space autonomy. TORU TANABE, TOSHIAKI KITAMURA, MASAYUKI IKEUCHI, TOSHIYUKI TANAKA, AKIRA AKASAKA et al., *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1293–1298.

Experimental validation of the GPS-INS-STAR hybrid navigation system concept is performed. First, an INS-STAR hybrid navigation system is constructed on the 3-axis motion table to verify the performance of its attitude loop. A GPS-INS hybrid navigation system is then installed on a car, and its translational performance is evaluated. Each result of the experiments is verified by theoretical analysis, and its feasibility for space application is evaluated. Through the experiments, the concept of the autonomous hybrid navigation is validated, and its potential in space autonomy is indicated.

A89-38191 How to reduce the fluctuation of space vehicle during manipulator movement. YOJI UMETANI and KAZUYA YOSHIDA, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1223–1230. 8 Refs.

Space vehicle fluctuation due toreaction forces from a vehicle-mounted manipulator is discussed. A new kinematic formulation is presented which is regarded as a further theoretical contribution from the viewpoint of robotics. This formulation includes a new form of Jacobian matrixused to define the manipulability measure for space robotic arms. The relationship between the fluctuation of the base vehicle and the manipulability of the installed manipulator is analyzed, and it is proved that high manipulability indicates low fluctuation. The theoretical results are applied to problems such as arm posture definition, path planning and configuration design, and ways to reduce the fluctuation of space manipulators are discussed.

A89-38181 Attitude control of a spacecraft during extension of flexible appendages. TAKESHI AOKI and HIROBUMI OHTA, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1159–1164.

This paper describes attitude dynamics and control of a flexible spacecraft which has a rotor and two reaction wheels inside of the rigid body and four flexible appendages attached outside of it. The effect of disturbances, which occur during extension of flexible appendages, on the attitude behavior is analyzed using the method of multiple scales. The vibration of the flexible appendages has a significant effect on the attitude motion of the spacecraft, which becomes unstable as the length of the appendages increases. However, it is shown that reaction wheels suppress the disturbances and can make the attitude motion stable.

A89-38178 A satellite sequence-of-event expert system. TOHRU OKATSU, TAKUJI TOHCHI, and MASARU YAMBE, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1135–1138.

An expert system is being developed to plan the sequence of events for the operation of a geostationary satellite in the transfer orbit phase. The system's functions are screen input, orbit calculation, event time inference, and screen/printer output. The conditions which influence the determinations of the sequence of events are described. Results are presented from two case studies, one under standard conditions and one in which apogee motor fire is executed at the second apogee.

A89-38113 Transient attitude analysis of satellites during deployment of elastic appendages. YUJI MATSUZAKI, TETSUYA HARADA, and KEIICHI KIMURA, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22–27, 1988, Vol. 1 (A89-3803116-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 643–648.

The attitude dynamics of a spinning satellitewith deploying flexible appendages is analyzed, considering both bending and torsional oscillations of the appendages to examine a dynamic interaction between the main rigid body and elastic appendages of the satellite. The effects of system parameters such as the spin rate and moment of inertia of the rigid body and the inertia, stiffness, and deployment rate of the appendages are studied. Equations of motion are obtained using a Lagrangian procedure and are solved numerically using the Gears method with automatic step-size adjustment and built-in error control.

A89-36703 Impulsive plasma waves observed by DE 1 in nightside magnetosphere. T. ONDOH, Y. NAKAMURA, S. WATANABE, and K. AIKYO, *Journal of Geophysical Research* (ISSN 0148-0227), Vol. 94, April 1, 1989, pp. 3779–3784. 17 Refs.

Wide-band electric field data received from DE 1 at Kashima station in Japan were studied via frequency-time spectral analysis. Impulsive plasma waves were observed at low geomagnetic latitudes in the outer magnetosphere around 0200 MLT during a geomagnetic quiet time on July 30, 1986, and also in the middle magnetosphere around 2300 MLT during a geomagnetic disturbed time on September 12, 1986. Impulsive plasma waves without strong narrow-band ELF hiss observed outside the plasmapause may be attributed to electrons bunched by a weak ELF hiss band in a nearby region or to space discharges occurring around the 200-m wire antenna on the DE 1 spacecraft.

A89-34925 Use of micro computer for satellite optical tracking control system. MASAO TAKABE, TOSHIKAZU ITABE, and TADASHI ARUGA, *Communications Research Laboratory Review* (ISSN 0914-9279), Vol. 34, Dec. 1988, pp. 239–243.

A study on computer system improvement is conducted, with a focus on a satellite optical tracking control system which is applied to spacecraft attitude measurement using a laser beacon. Real-time control and data processing for this system are accomplished with a minicomputer system. In recent years, intensive efforts resulted in a new PC-based system, developed and modified, as a replacement. The successful efforts resulted in a five times greater access speed, smaller size, price reduced to about one tenth the former cost, and the same computing accuracy as the present system.

A89-33096 The solar pressure torque and the design of the attitude control system of the communication satellite with large antenna reflectors. MASAZUMI UEBA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 37, No. 420, 1989, pp. 14–20. 14 Refs.

In this paper, the solar pressure torque of the 2-ton class satellite with two antisymmetric antenna reflectors was calculated. Then, the structure which causes large solar pressure torque was considered numerically. Based on the results, especially the secular and periodical component of the roll/yaw plane solar pressure torque, it was revealed, how to decide the magnitude of the bias momentum of the bias momentum attitude control system from the point of yaw error requirement. It was confirmed that simulation values agree well with the theoretical results.

A89-30792 Integrated direct optimization of structure/regulator/observer for large flexible spacecraft. JUNJIRO ONODA and NAOYUKI WATANABE, Technical Papers of the 30th AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference—Part 3, Mobile, AL, Apr. 3-5, 1989, (A89-30651 12-39). Washington, DC, American Institute of Aeronautics and Astronautics, 1989, pp. 1336-1344. 18 Refs. (AIAA Paper 89-1313).

An numerical direct approach to design an optimal controller composed of regulator and observer has been proposed for integrated structure/controller optimization of flexible spacecraft. The approach takes account of uncontrolled residual modes. Therefore, it does not only optimize based on an actual performance index degraded by the residual modes but also suppresses the spillover instability. The approach has been applied to a simply supported beam examples first, and the characteristics of the resulting system have been investigated. The examples have demonstrated that the resulting controller is stable even when LQG controller is unstable. Insensitivity of the resulting system to parameter variations is also demonstrated compared with LQG controller. Subsequently, the approach has been incorporated in a structure/controller simultaneous optimization scheme. The practicality and effectiveness of the present scheme has been demonstrated in a beam-like flexible spacecraft example.