Japanese Aerospace Literature
This month: *Orbital Mechanics*

A95-27226 Strong Hohmann transfer theorem (for calculating circular-to-conical coplanar orbits). F. YUAN and K. MATSUSHIMA (National Aerospace Lab., Chofu, Japan), *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), Vol. 18, No. 2, 1995, pp. 371–373. 7 Refs. Documents available from Aeroplus Dispatch.

In this paper, two lower bounds of velocity changes for orbital transfer from a circular orbit into a coplanar conical orbit (and vice versa) are found. Since the values of these two bounds are the same as those used in the Hohmann transfer between two coplanar circular orbits, the result is called the strong Hohmann transfer theorem. This theorem also means that, for any given delta-V, the maximum radius change from a circular orbit can be attained by applying the delta-V tangentially. A proof of this theorem is presented here. The strong Hohmann transfer theorem is then applied to show that the Hohmann transfer is optimal compared with other two-impulse transfers, not only in total velocity change, but also in each velocity change.

A95-12732 Long-term analysis for the orbital changes of debris. M. YOSHIKAWA (Kashima Space Center, Japan), *Proceedings of the 18th International Symposium on Space Technology and Science*, Kagoshima, Japan, 1992, Vol. 2 (A95-12376 01-12), Tokyo, Japan, AGNE Publishing, Inc., 1992, pp. 2403–2408. 2 Refs. Documents available from Aeroplus Dispatch.

We investigate the motions of debris in a large time scale by using a numerical integration technique. We obtain the evolution of orbits of debris by integrating the equations of motion in the Newtonian frame. The perturbations that we take into account are nonspherical geopotential terms up to the 10th order, the gravitations of the sun and the moon, and the solar radiation pressure. As for the motion of the Earth, we assume that the Earth is rotating and precessing uniformly. We calculate the orbital evolution of objects that exist mainly around the geosynchronous orbit. The calculated periods are from 10 to 500 years. The range of motion is obtained as functions of initial values of semimajor axis, initial values of longitude, and solar radiation pressure. Close encounters between objects for a model distribution of debris are also analyzed. (Author)

A94-30522 An approach to dynamics and control of flexible systems. T. NAGATA, H. MATSUO (Inst. of Space and Astronautical Science, Sagamihara, Japan), V. J. MODI (British Columbia, Univ., Vancouver, Canada), *AIAA/AAS Astrodynamics Conference*, Scottsdale, AZ, 1994, TP (A94-30483 10-12), Washington, DC, American Inst. of Aeronautics and Astronautics, 1994, pp. 366–375. 5 Refs. Documents available from Aeroplus Dispatch.

A general formulation is presented, applicable to a large class of rigid/flexible multibody systems, which accounts for an arbitrary level of branching, the character of the structural members, and orbital perturbations. Based on the formulation, a numerical simulation code was developed which showed high accuracy in terms of system energy and angular momentum conservation. The versatility of the formulation is illustrated by its application to two distinctly different cases: librational analysis of the Space Shuttle and the Space Station based Mobile Manipulator System.

A94-18813 Dynamics of large space structure elements in orbit through adaptive deployment construction. M. C. NATORI (Inst. of Space and Astronautical Science, Sagamihara, Japan), H. NAMBA (Shimizu Corp., Tokyo, Japan), K. C. PARK (Colorado Univ., Boulder), and J. C. CHIOU (National Chiao Tung Univ., Hsinchu, Taiwan), *Smart structures and materials 1993: Smart structures and intelligent systems; Proceedings of the Meeting*, Albuquerque, NM, 1993 (A94-18726 03-39), Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1993, pp. 1042–1051. 11 Refs. Documents available from Aeroplus Dispatch.

By using a modular multibody dynamics code, the dynamic behavior of space structure elements is investigated to get an effective construction scenario for large space systems in orbit. Deployment construction of a triangular key structure for a solar power satellite in low Earth orbit is treated, and the dynamical responses through the deployment in orbit plane, orbit normal, or parallel plane are simulated. Illustrative examples clearly show the large variety of resulting dynamical behavior during and after deployment construction. (Author)

A93-51984 New method for the numerical integration of an N-body system in an external potential. H. EMORI (Tokyo Inst. of Technology, Japan), S. IDA (Tokyo Univ., Japan), and K. NAKAZAWA (Tokyo Inst. of Technology, Japan), *PASJ: Publications of the Astronomical Society of Japan* (ISSN 0004-6264), Vol. 45, No. 3, 1993, pp. 321–327. 11 Refs. Documents available from Aeroplus Dispatch.

A newly developed numerical-integration method is presented. It has a great advantage when used to numerically calculate the orbital motion of mutually interacting planetesimals in a strong external (the solar gravitational) field. In an ordinary difference scheme, since the effect of a weak mutual gravity would be embedded in the truncation error of the strong solar gravity, we cannot reflect the small, but important, effect of mutual gravity on the numerical calculation. Our new method helps us to overcome this difficulty by suppressing the truncation error of numerical integration. The essence of our method is to express a solution as a sum of unperturbed and perturbed solutions: the former represents the motion only under an external field; the latter represents a small deviation from an unperturbed orbit due to mutual gravity between planetesimals. The perturbed solution is found by means of an ordinary integrator, whereas an unperturbed solution is sought by a higher-order integrator (or, by an analytical manner). By this method, we can integrate orbits both accurately and speedily. Since our method has a very simple algorithm, we can apply it to well-known numerical integration methods, such as the Runge–Kutta method and the Predictor–Corrector method.

A93-48483 A numerical study of gravitational capture orbit in the Earth-moon system. H. YAMAKAWA (Tokyo Univ., Japan), J. KAWAGUCHI, N. ISHII, and H. MATSUO (Inst. of Space and Astronautical Science, Sagamihara, Japan), *Spaceflight mechanics 1992; Proceedings of the 2nd AAS/AIAA meeting*, Colorado Springs, CO, 1992. Pt. 2 (A93-48426 20-12). San Diego, CA, Univelt, Inc., 1992, pp. 1113–1132. 21 Refs. Documents available from Aeroplus Dispatch.

Gravitational capture is a mechanism by which an object from outside the sphere of influence can orbit around a celestial body temporarily, without any other effects such as atmospheric drag. In this paper, gravitational capture conditions are extensively sought laying emphasis on lunar capture portion using backward time integration mainly in the Earth-moon-S/C three-body system. Perilune velocity band satisfying the gravitational capture conditions is found to be constituted of three subbands mainly corresponding to its capture direction in the Earth-moon fixed rotating frame. An analysis of geocentric orbit with solar effect linking the Earth and lunar gravitational capture orbit is also performed for construction of Earth-moon transfer orbit. Transfer orbits of various types are designed in the sun-Earth-moon-S/C four-body system, which indicate the feasibility of gravitational capture with reasonable Delta V and flight time. (Author (revised))

A93-45936 Predictions of the meteor radiant point associated with an Earth-approaching minor planet. I. HASEGAWA (Otemae Junior College, Itami, Japan), Y. UEYAMA, and K. OHTSUKA (Tokyo Meteor Network, Japan), *PASJ: Publications of the Astronomical Society of Japan* (ISSN 0004-6264), Vol. 44, No. 1, 1992, pp. 45–54. 29 Refs. Documents available from Aeroplus Dispatch.

Predictions of meteor orbits and radiant points are presented for Earth-approaching minor planets discovered before the end of 1989. All meteor orbits available from the IAU Meteor Data Center (Lund Observatory) are compared to our predictions, and, on the basis of orbital similarity, possible identifications are found. Besides (3200) Phaethon, the parent body of the Geminids, (2201) Oljato is likely to be another most probable candidate for an extinct comet, belonging to the Taurid complex. In addition, several meteors possibly associated with (4450) Pan = 1987 SY and 1988 TA are also found.

N93-28047 Mars revolving observation satellite Kasei Shuukai Kansoku Eisei. M. TAJIMA, Tokyo (Japan), *NASDA, Future Space Activity Workshop: Lunar Base Workshop*, 1992, p. 18 (SEE N93-28014 10-12). Documents available from Aeroplus Dispatch.

A study concerning the possibility of a Mars revolving satellite, to be launched in the first part of the 21st century, is presented. It is believed that this is a necessary step before proceeding to Mars landings, bases, and further exploration. The mission requirements are as follows: 1) a precision Mars mapping, including topography information; 2) a Mars resources exploration by spectral absorption examination of the Mars surface; 3) a Mars atmospheric investigation; 4) a survey of the Mars polar cap; and 5) a radioactive environment survey. The system structure, electric power and weight analysis, and fuel analysis are presented. A subsystem analyses concerning attitude control, communication, electric power, data processing, and propulsion and reaction control subsystems is also provided. (Author)

N93-28046 Detail design of Mars transfer orbit (Kasei Seni Kidou Shousai Sekkei). K. OOTA, K. NAKAZIMA, and K. NAGANO, *Future Space Activity Workshop: Lunar Base Workshop*, 1992, p. 20 (SEE N93-28014 10-12). Documents available from Aeroplus Dispatch.

An overview of interplanetary transfer orbit simulations and orbit injections is presented. The process for setting initial values (injection date and orbit elements at the orbit injection) was developed from the values obtained by the conceptual study. The following design concerns are considered: the velocity vector at injection; a transfer orbit that neglects the Earth's gravity; the velocity vector upon reaching Mars–neglecting Mars's gravity; velocity increments necessary at perigee and apogee; and flight time. Necessary speed increments and the Mars true anomaly at the transfer orbit injection were used to determine the transfer orbit injection date. (Author)

N92-33790 Fly-back boosters (Furai bakku busuta). T. MAKINO and S. MATSUDA, *NASDA, Future Space Activities Workshop: Lunar Base Workshop*, 1991 p. 13 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

The first system review on rocket systems composed of fly-back booster and expendable upper-stage rockets which are capable of launching a payload of 30 tons into low Earth orbit is conducted. Three types of winged reusable fly-back booster systems are reviewed on the following premises: 1) payload launch capability of 30 tons; 2) start of operation in the years 2000–2010; 3) two-staged vertically launched vehicles; and 4) the core will be a LH2/LOX two-stage launch vehicle with LE-7A rocket engines. 2nd-stage fundamental features, booster stage aerodynamic design, aerodynamic performance estimates, booster stage sizing, orbit analysis, and system trade-off of the fly-back boosters are reviewed. Fly-back booster launch vehicle flight sequence, 2nd-stage features, configuration and characteristics of three types of rocket system, and fly-back booster orbit condition histories are outlined. (Author)

N92-33771 Lunar soft landing orbit design (Tsuki nanchakuriku kidou sekkei). K. NAKAJIMA and K. NAGANO, *NASDA, Future Space Activities Workshop: Lunar Base Workshop*, 1991, p. 21 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

The following subjects necessary for lunar soft landing orbit design are reviewed: 1) methods to solve minimum fuel consumption problems; 2) lunar soft landing orbit design based on the results of the fuel consumption problems; and 3) future problems. The answer to the minimum fuel consumption by Pontryagin's maximum principle are presented. Lunar soft landing orbit design using a spherical model are presented for four assumed cases. Powered descending time-altitude profile, transient angle-altitude profile, powered descending time-vertical speed profile, powered descending time-control angle profile, and powered descending time-speed profile in down-range direction are showed. The following has become clear: 1) when powered descent begins from an elliptical orbit, starting from the perigee point is advantageous if the speed increase necessary for landing is employed as the criteria; and 2) constant thrust acceleration level exists to minimize necessary speed increase. (Author)

N92-33767 Review on Phobos sample retrieval mission (Fobosu sanpuru kaishuu misshon no kentou). N. NAGAOKA, *NASDA, Future Space Activities Workshop: Lunar Base Workshop*, 1991, p. 22 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

The purpose of the Phobos sample collection mission is to rendezvous with the Mars satellite Phobos, conduct observation of its surface, and collect and return samples to the Earth. The sample return satellite for achieving the mission will be injected into the Mars revolving orbit by a H-2 launch vehicle and an Orbit Transfer Vehicle (OTV). The satellite will stay on the Phobos surface till the Earth and Mars are in favorable positions relative to each other. Reviews are conducted on the following items: 1) onboard mission equipment; 2) the mission profile of injection into the revolving orbit of Mars, access to and landing on Phobos, and sample return to the Earth; 3) methods of fixing the satellite on the surface of Phobos; and 4) sample retrieving to the Earth. The following subsystems of the satellite system are reviewed: 1) the electric power subsystem; 2) the data processing communication subsystem; 3) the attitude and orbit control subsystem; 4) the propulsion subsystem; 5) the thermal control subsystem; 6) the structure subsystem; 7) the sample retrieving probe; and 8) the satellite configuration. (Author)

N92-33764 Mars landing exploration mission (Kasei chakuriku tansa misshon). M. SUZAKI, *NASDA, Future Space Activities Workshop: Lunar base Workshop*, 1991, p. 22 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

The overall concept for Mars observation missions and the systems to implement the missions are reviewed. Reviews are conducted on the following items: 1) profiles of the candidate missions; 2) aerodynamic capture deceleration estimates; 3) prospective Mars orbit decisions; 4) landing methods as the prerequisites for mission accomplishment; and 5) explorer systems to accomplish the missions. The major processes involved in the mission, from the launch to the beginning of observation of the surface, are outlined. Reviews of possible orbits taken by the explorer from Mars transfer orbit (Hohmann orbit) to Mars revolving orbit are presented. Additionally, the possible orbits for the landing vehicle from departing from the revolving orbit through landing are presented. Transportation and landing module design concepts concerning the structure, weight, and electric power balances of the explorer system are presented. Critical Mars mission technologies are cited as follows: 1) interplanet navigation; 2) aerodynamic capture; 3) automatic and autonomous operation; and 4) landing technology. (Author)

N92-33762 Mars revolving observation satellite (Kasei shuukai kansoku eisei). T. OKAZAKI, T. NAKANO (Nippon Electric Co. Ltd., Japan), and M. INOMATA (Nippon Electric Co. Ltd., Japan), *NASDA, Future Space Activities Workshop: Lunar Base Workshop*, 1991, p. 22 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

The features that will be considered for observation on Mars are reviewed. The mission requirements, which are dictated by the features, are discussed. The mission scenarios assume the utilization of the H-2 launch vehicle. Additionally, spacecraft system structures are reviewed. Features that will be considered for observation by Mars satellites are as follows: 1) topographical and geographical features of the Mars surface; 2) material compositions and mineral resources on the Mars surface; 3) composition, pressure, and water vapor content of the Mars atmosphere; 4) vertical structure of the Mars atmosphere; and 5) the climate on Mars (clouds, polarcaps, and sand dusts). Mission operational requirements for exploration vehicle configurations (Mars-oriented and Earth-oriented), including mission equipment installation, onboard data processing, communication, attitude control, electric power source, and solar paddle systems, are reviewed. It is concluded that the Earth-oriented configuration is suitable for high-resolution local topography missions and the Mars-oriented configuration is suitable for atmospheric observation of the Martian surface. (Author)

N92-33761 Mars exploration mission (Kasei tansa misshon). S. MATSUDA, *NASDA, Future Space Activities Workshop: Lunar Base Workshop*, 1991, p. 22 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

Mars exploration scenarios are reviewed. An emphasis is placed on scientific exploration. The review and evaluation results are reported for the following items: 1) orbit plans for Mars surface exploration missions that begin in Low Earth Orbit (LEO); 2) powered and aerodynamic capturing payloads from the transfer orbit to a Mars revolving orbit; and 3) a penetrator system as a Mars landing vehicle. Proposed Mars transfer orbits have the following advantages over Hohmann orbits: 1) transfer time and angle are less; 2) the inclination between the orbital planes of Earth and Mars is considered; and 3) velocity variations are not required to change orbit plane. (Author)

N92-33760 Unmanned Mars exploration mission (Mujin Kasei tansa misshon). T. MAEDA, *Future Space Activities Workshop: Lunar Base Workshop*, 1991, p. 24 (SEE N92-33753 24-91). Documents available from Aeroplus Dispatch.

Reviews of the unmanned Mars exploration missions and their candidate spacecraft are presented. The results of initial analyses are reported for the following: 1) Mars transfer orbits; 2) launching by H-2 launch vehicles and injection into Mars orbits; and 3) return-to-Earth orbits. The purpose, system outline, and necessary equipment are presented for the following spacecraft: 1) Mars Moon Sample Return (MMSR) (from Phobos and Deimos); 2) Mars Landing Explorer (MALE); and 3) Mars Mobile Explorer (MAME). (Author)

N92-33753 Future Space Activities Workshop: Lunar Base Workshop 1991 (Shourai no Uchuu Katsudou Wakushoppu: Getsumenkichi Wakushoppu 1991). National Space Development Agency, Tokyo (Japan). Documents available from Aeroplus Dispatch.

Proceedings from the conference are presented in veiwgraph form. The following topics were discussed: manned space activity, manned service platforms, life support system, space shower, Japanese space programs, Mars explorations, Mars observation satellites, atmospheric reentry, Mars landing and exploration missions, scientific exploration vehicles, sample return missions, International Asteroid Mission, lunar explorations, lunar soft landing, lunar module, lunar surface vehicles, manned lunar surface sites, lunar surface robots, lunar base construction, nuclear power plants, solar power generation, space transportation systems, fly-back boosters, international cooperation, miniaturizing artificial satellites, and space manufacturing. For individual titles, see N92-33754 through N92-33799. (Author)

A92-54384 Gravitational wave burst produced by merging of central black holes of galaxies. T. FUKUSHIGE, T. EBISUZAKI, and J. MAKINO (Tokyo, University, Japan) *Astrophysical Journal, Part 2—Letters* (ISSN 0004-637X), Vol. 396, No. 2, 1992, pp. L61–L63. 25 Refs. Documents available from Aeroplus Dispatch.

When galaxies merge, the central black holes rapidly sink toward the center of the system and make a binary. It is found that this black hole binary merges within less than or approximately equal to 10 exp 9 year. This merging of black holes produces an intense burst of the gravitational wave. The nature of these gravitational wave bursts, is investigated, and it is found that the dimensionless amplitude at the Earth is as high as 10 exp −15 if black holes with massesof 10 exp 8 solar masses merge at the distance of 2 Gpc. The mean time between bursts is about 2 year if the elliptical galaxies are the merger remnants of galaxies having central black holes. It is found that dynamical friction makes the orbit highly eccentric. The lifetime of a binary with a highly eccentric orbit is much shorter than that of a binary with a circular orbit, because the emission of the gravitational wave is much stronger for shorter periastron distance. (Author)

A92-31106 Secular perturbations of fictitious satellites of Uranus. H. KINOSHITA and H. NAKAI (National Astronomical Observatory, Mitaka, Japan) *Celestial Mechanics and Dynamical Astronomy (ISSN 0923-2958)*, Vol. 52, No. 3, 1991, pp. 293–303. 5 Refs. Documents available from Aeroplus Dispatch.

Secular perturbations of fictitious satellites that are initially circular and in the equatorial plane of Uranus are discussed. Satellites located in the region where the solar perturbation is dominant become highly eccentric and inclined with respect to the equator, and have a possibility to collide with Uranus. Satellites located in the region where the oblateness perturbation is dominant keep the original eccentricity and the inclination. A scenario of a possible extinction of outer satellites of Uranus is also discussed. (Author)

N92-17854 Systematic computation algorithm to obtain osculating orbit elements from position and velocity vectors (ICHI SOKUDO BEKUTORU KARA SESSHOKU KIDO YOSO WO MOTOMERU HOKATSUTEKINA KEISAN ARUGORIZUMU). T. SHIHO, National Aerospace Lab., Tokyo (Japan). Control Systems Div. Documents available from Aeroplus Dispatch.

This report describes calculation algorithm and its systematic procedure of osculating orbital elements computation in each case of ecliptic, parabolic, hyperbolic and rectilinear orbit. The osculating orbital elements are those elements applied only in specific timing when position vector and velocity vector of a spacecraft or celestial body, such as comet, are input in the calculation. (Author)