Welcome

to the 17th International Symposium on Space Flight Dynamics

Space exploration and exploitation bring to the specialists in space flight dynamics new challenges. And international symposiums on space flight dynamics taking place in different countries give to them an opportunity to regularly exchange views and thus contribute to further progress in this sphere.

The 17th Symposium takes place in Moscow. I am very happy to meet here again my colleagues after a long interval (last time such a Symposium was held in Moscow in 1994). This Symposium is held by the Russian Academy of Science (Keldysh Institute of applied mathematics). And was organized with the active participation of Space Informatics Analytical Systems Joint Stock Company (KIA Systems) and of Moscow City Palace for Children (Youth) Creativity. In the work of the Symposium on the Russian side besides Keldysh Institute also participate Research Institutes of the Russian Academy of Science (Space Research Institute, Institute of Astronomy etc), Divisions of the Russian Space and Aviation Agency (Mission Control Center, Rocket and Space corporation Energy).

Sessions will be held in the conference-hall of Moscow City Palace for Children (Youth) Creativity. The following sessions will be held within the framework of Symposium:

Flight Dynamics Operations
Orbit determination
Attitude Dynamics, Estimation, Control
Orbit Design
Mission Analysis
Maneuvers Design, Guidance, Control
Atmospheric Entry
Autonomous Navigation, GPS Navigation
Low Thrust Trajectories
Deep Space Missions
Formation Flying, Constellation
Celestial Mechanics
Flight Dynamics Software
Space Debris Dynamics

Regarding previous symposiums session Space Debris Dynamics is absolutely new. Her appearance was caused by the growing interest to this problem and new results received in this sphere.

I thank a lot participants of the Symposium for the work they have done and for the prepared reports and I wish you all a productive work.

Efraim Akim,
ISSFD Program Chair

Location
Conference session will be held in the Moscow City Palace for Children (youth) Creativity (MCPCYC). MCPCYC is located in Kosygin street, 17.

Sessions
Each presentation will last 20 minutes, including time for questions and answers.

Registration
Registration will be held in MCPCYC on Monday, 16 June from 8:00 to 9:40. The registration fee is US$500

Program Committee
E. Akim (Chairman), Keldysh Inst. Appl. Mathematics
D. Okhotsimsky, Keldysh Inst. Appl. Mathematics
J. Campbell, NASA
L. Cangahuala, Jet Propulsion Laboratory
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R. Münch, European Space Operations Center
N. Ivanov, Rosaviakosmos Mission Control Center
V. Orlando, Instituto Nacional de Pesquisas Espaciais
T. Stengle, NASA Goddard Space Flight Center
V. Stepaniants, Keldysh Inst. Appl. Mathematics
A. Tuchin, Keldysh Inst. Appl. Mathematics

Schedule

16 June 2003 Monday	17 June 2003 Tuesday	18 June 2003 Wednesday	19 June 2003 Thursday	20 June 2003 Frisday
8:00-09:40 Registration	8:20-10:00, Session 4 Low Thrust Trajectories	8:20-10:00, Session 8 Attitude Dynamics, Estimation, Control	8:20-10:00, Session 11 Formation Flying, Constellation. Maneuvers Design, Guidance, Control	8:20-10:00, Session 15 Celestial Mechanics
09:40-10:00 OPENNING	10:00-10:20, Break	10:00-10:20, Break	10:00-10:20, Break	10:00-10:20, Break
10:00-12:00, Session 1 Flight Dynamics Operations	10:20-12:00, Session 5 Orbit Design, Mission Analysis	10:20-12:00, Session 9 Flight Dynamics Software	10:20-12:00, Session 12 Orbit Determination	10:20-12:00, Session 16 Low Thrust Trajectories
12:00 – 13:30, Lunch	12:00 – 13:30, Lunch	12:00 – 13:30, Lunch	12:00 – 13:30, Lunch	12:00 – 13:30, Lunch
13:30-15:30, Session 2 Space Debris Dynamics, Space Patrol Systems	13:30-15:30, Session 6 Deep Space Missions	13:30-15:30, Session 10 Attitude Dynamics, Estimation, Control	13:30-15:30, Session 13 Orbit Determination	Excursion
15:30 - 15:50, Break	15:30 - 15:50, Break	Excursion	15:30 - 15:50, Break	
15:50-17:30, Session 3 Autonomous Navigation, GPS Navigation	15:50-17:30, Session 7 Atmospheric Entry		15:50-17:30, Session 14 Attitude Dynamics, Estimation, Control	
			Symposium Dinner	

16 June 2003, Monday

Session 1
Flight Dynamics Operations
10:00-12:00

01-1. THE REENTRY OPERATIONS FOR ASTRA 1K
Etienne DUCROTTE, Jean-Paul BERTHIAS, Beatrice DEGUINE, Francois DESCLAUX, Jacques FOLIARD, Laurent FRANCILLOUT, Hubert FRAYSSE, Jean-Francois GOESTER, Marc ROSSI, Stephane ROUSSEAU, Francois LAPORTE
CNES, France

Abstract

Following a failed Proton launch, the satellite of telecommunications Astra1K was released on an orbit of 175 km altitude and 51 degree inclination. This presentation intends to describe the operations that have come to a controlled re-entry early on the 10/12/2002. The work began with two maneuvers to raise the orbit up to an altitude of 290 km. From this time, analyses were undertaken to allow a decision process that came to decide to de-orbit the spacecraft. The presentation focuses on the orbit propagation troubles, the available attitudes to perform the maneuvers, the studied scenarios and the operational sequences.

01-2. INTEGRAL - FULLY AUTOMATIC FLIGHT DYNAMICS REAL-TIME SUPPORT DURING THE ROUTINE SCIENCE PHASE
Frank Dreger
ESA-ESOC (TOS-GFT), Germany

Abstract

INTEGRAL - ESA's first gamma-ray observatory - was launched on 17. October 2002. Together with XMM-Newton it is the second, currently flying observatory mission, which requires real-time operations support during 24 hours per day and 7 days per week.

The paper describes the individual tasks, the user requirements, and the experience gathered during the first months of INTEGRAL routine operations. The paper also addresses the limitations experienced when Flight Dynamics tools are provided to non-Flight Dynamics staff.

01-3. THE INTEGRAL WHEEL PROFILE PLANNING STRATEGY

Rainer Kresken
EDS, Germany

Abstract

ESA's INTEGRAL is equipped with a reaction wheel assembly consisting of four wheels for attitude control. A thruster-based reaction control system allows momentum bias maneuvers. The presentation describes the measures to comply to the wheels' operational constraints with optimum operational efficiency and minimum interference with scientific observations and gives a comparison with the operations of ESA's XMM x-ray observatory

01-4. A PLATFORM-INDPENDENT SOLAR-LUNAR-PLANETARY PACKAGE FOR FLIGHT DYNAMICS APPLICATIONS BASED ON METHODS FROM THE BUREAU DES LONGITUDES

Robert A. McCUTCHEON
Hubble Space Telescope Science Institute / Computer Sciences Corp, USA

Abstract

This paper describes a new platform-independent solar-lunar-planetary (SLP) ephemeris package based on theories and models developed at the Bureau des longitudes (BDL) Institut de mecanique celeste et de calcul des ephemerides. For the Moon the new package uses ELP 2000-82B, a semi-analytic theory that agrees with the Jet Propulsion Laboratory (JPL) LE200 ephemeris to within 0.03 arcseconds. For the Sun and planets the new package uses the BDL Poisson series method. The coefficients for these series were determined via frequency analysis of the JPL DE403 ephemerides from 1900 to 2100. The largest differences between geocentric positions computed via the BDL Poisson series and positions computed directly from DE403 are on the order of a few milli-arcseconds. The BDL SLP package also uses the Poisson series method to provide ephemeris data for the minor planets Ceres and Vesta. All coefficients are read from flat ASCII files, thereby making the new SLP package usable without modification on both VMS and Unix platforms. The new package has replaced the JPL-based SLP package in all Hubble Space Telescope Payload Operations Control Center Applications Software Support systems.

01-5. ESA/ESOC FIRST ACQUISITION STRATEGIES

G. Ziegler
Electronic Data Systems, European Space Operations Centre, Germany

Abstract

Unlike other space agencies ESA ground stations are not equipped with special first acquisition antennas which ease the first acquisition because of their large beam

width. To overcome this disadvantage some standard search strategies are used which essentially scan the sky spirally around the nominal pointing direction with increasing radii. These standard strategies are completed by special mission dedicated strategies sometimes in order to detect the spacecraft as soon as possible. In this presentation three basic techniques, namely spiral search, waiting point method and horizon-scan technique, will be described as well as their potentially expected benefit for the missions Proba and Integral.

01-6. ESA/ESOC APPROACH TO STATION PLANNING AND SCHEDULING
B. Santa-Cruz
GMW at ESA/ESOC, Germany
Detlef Sieg
EDS at ESA/ESOC, Germany

Abstract

It is of high economic interest for ESOC to know the workload of its globally distributed network of ground stations. Then as many support requests as possible can be committed. For this an automated process and an appropriate software tool supporting short-term scheduling and long-term forecast are necessary. The user requirements and the design of the tool are described and a long-term analysis of some ESA missions is illustrated.

Session 2
Space Debris Dynamics
13:30-15:30

02-1. LONG-TERM EVOLUTION OF DEBRIS CLOUDS IN GEOSYNCHRONOUS ORBIT
Carmen Pardini, Luciano Anselmo
ISTI/CNR, Italy

Abstract

During the 1990s, it became clear that spacecraft and upper stage breakups contributed to the GEO debris environment while, recently, optical observations have confirmed the presence of a large population of decimeter sized particles, probably generated by a number of undetected explosions. Hoping to provide the optical observers with useful information and clues in identifying and characterizing the past explosion events near the geosynchronous region, a fragmentation in GEO of a typical communication spacecraft has been simulated, while assuming a reasonable range of the fragments' ejection velocities. Each produced debris cloud has been propagated for 72 years, saving the results at intermediate time steps. The final outcomes - mainly represented as snapshots, at a given post-explosion time, in the

orbital elements space - show the long- term evolution of each debris cloud as a function of debris size and ejection velocity.

02-2. COLISION OF SPACECRAFT WITH DEBRIS PARTICLES ASSESSMENT

A.I. Nazarenko
Rosaviakosmos Space Observation Center, Russia

Abstract

The problem of estimating the possibility of collisions of space debris (SD) is relatively new. This paper presents the results of investigations of key problem of collision hazards evaluation: (a) current SD environment, (b) technique for collision probability evaluation, (c) characteristics of the relative flux of SD, (d) account of shape and orientation of typical spacecraft modules, (e) characteristics of the new software for the SD impact hazards evaluation. The test penetration probability calculations are performed; the related results are presented and analysed.

02-3. GEO OBJECTS CATALOGUE MAINTENANCE AND ANALYSIS OF ACCURACY OF GEO TLE ARCHIVE

Z.Khutorovskiy, V.Boykov, V.Agapov, N.Sbytov, A.Samotokhin
Keldysh Insitute of Applied Mathematics, KIA Systems

New geostationary objects (GEO) catalogue had developed. It is based on complex informational model in the Oracle 8 RDBMS environment, highly efficient orbital motion and orbital determination models. Special tasks developed for measurements and orbits identification. Optical measurements obtained by ground stations of the Russian Academy of Sciences during period of 1975-2002 had processed as well as TLE archive for GEO objects. Unique results on large volume of TLE accuracy estimation obtained. The paper will present general architecture of the Catalogue, description of motion model and orbit determination model (including initial orbit estimation based on optical measurements only), results of data processing, general characteristics of GEO objects environment.

02-4. POSSIBILITY OF NEAR REAL-TIME TRAJECTORY MEASUREMENTS WITH VLBI RADAR METHOD

I. E. Molotov, G. Tuccari, B. N. Lipatov, X.Y. Hong
KIAM, Russia

Abstract

The method allows to measure all movement parameters of space objects by combining the VLBI and radar techniques. The system consists of powerful ground radar (Evpatoria), three VLBI radio telescopes (Noto, Bear Lakes, Shanghai) and the correlator in Noto. The received telemetry or radar echo signals are transferred from radio telescopes to processor through Internet for cross-correlation in near real-time.

This system is acceptable for investigations of the dynamics properties of space debris objects, operating satellites, deep space spacecrafts, asteroids and planets. This work is supported by INTAS 2001-0669 and RFBR 02-02-17568 grants.

02-5. SPACE PATROL SYSTEM

T.M.Eneev, G.B.Efimov, R.Z.Akhmetshin, G.S.Zaslavsky
KIAM, Russia

Abstract

Conception of space patrol system for discovering hazard asteroids is considered. The patrol system with several spacecrafts (with space telescopes onboard) on the Earth orbit allow to discover during 5-6 years a lot of asteroids (with diameter ? 100 m) approaching the Earth orbit. Conception may be considered as the following step to existing programs of optical observation from the Earth of dangerous objects (with diameter 1 km)

Session 3
Autonomous Navigation, GPS Navigation
15:50-17:30

03-1. THE ATV FAULT TOLERANT AUTONOMOUS ATTITUDE DETERMINATION AND NAVIGATION

J.L. Gonnaud, R. Fayard,
ASTRIUM, France

Abstract

The Automated Transfer Vehicle (ATV) is a European cargo transfer vehicle designed to carryout ESA in-orbit replenishment missions to the International Space Station. The ATV first flight is currently planned in 2004. Due to its very specific rendezvous mission toward a manned orbital facility, the Navigation function has to fulfil drastic reliability and availability requirements. These requirements are designed to ensure an unequalled level of Safety with respect to collision hazards regarding the ISS. This paper provides a deeper insight into some innovative solutions that have been implemented in the ATV navigation (attitude and relative position) to allow the fulfilment of these very stringent GNC requirements. The latest status of validation of the flight software is presented, including performances validation through statistical simulation campaigns.

03-2. A SURVEY OF AUTONOMOUS ORBIT CONTROL INVESTIGATIONS AT INPE

Valcir Orlando, Helio Koiti Kuga,
INPE, Brazil

Abstract

A survey of the research on autonomous orbit control systems carried out at INPE is presented. INPE started working in this area in 1995 when an study on the feasibility of an autonomous control concept of the orbit longitude phase drift (DL0) was performed, in cooperation with the French Space Agency (CNES). The use of DIODE (French autonomous navigator) simulated orbit observations was considered. Thereafter, following a world wide trend, the research work was re-directed to the investigation on the use of the GPS (Global Positioning System). At first, only the direct use of the coarse GPS navigation (geometric) solution was considered. In order to improve the results of the GPS based autonomous control, a GPS simplified navigator was developed and included in the control procedure. Samples of the results obtained in each phase of the research work are presented and commented in the work.

03-3. GPS ERRORS STATISTICAL ANALYSIS FOR GROUND RECEIVER MEASUREMENTS

E.L. Akim, D.A. Tuchin,
Keldysh Institute of Applied Mathematics RAS

Abstract

The creation of a autonomous spacecraft's control system with use GPS requires the statistical analysis of GPS error measurements. This work describes a most GPS receiver error measurements. The pseudorange of the C/A-Code measurements were processed and analysed to obtain the statistical performances of the three main sources of GPS error: GPS satellite errors (ephemeris and satellite clock), the Earth atmosphere errors (ionosphere and troposphere), user receiver errors (frequency drift, pseudo-noise sequence phase drift, signal detection time). It allowed to exclude the mentioned errors from common error budget to construct the statistical model of proper error of pseudorange measurements and to study the influence of their separate components on user state vector determination. The comparison of predicted measurement precision with real pseudorange of the C/A-Code was conducted out.

03-4. DETERMINING ORBIT OF THE INTERNATIONAL SPACE STATION BY USE OF GPS MEASUREMENTS

M.Yu.Beliaev, DN.Rulev, E.S.Medvedev,
RSC Energia, Russia,
V.V.Sazonov
Keldysh Institute of Applied Mathematics RAS, Russia

Abstract

The GPS receivers are installed on the Russian and American Segments of ISS to realize high-precision navigational support of its flight. The receiver in the Russian Segment is ASN-2401. Its trial was begun in 2001. It is intended for using in the structure of the motion and navigation control system of the Service Module. Our paper presents some estimations of actual accuracy of the receiver, which were obtained by smoothing of GPS-measurements on time intervals of various lengths.

17 June 2003, Tuesday

Session 4
Low Thrust Trajectories
08:20-10:00

04-1. THE ATTITUDE AND ORBIT CONTROL SYSTEM ON THE SMART-1 LUNAR PROBE

Per Bodin
Swedish Space Corporation, Sweden

Abstract

SMART-1 is the first in a series of low-cost scientific missions by the European Space Agency. The mission of SMART-1 is to demonstrate the use of electric primary propulsion in a low-thrust transfer orbit from earth orbit into lunar orbit. The mission consists also of several scientific measurements mainly for use in lunar orbit. The Swedish Space Corporation is the prime contractor for the spacecraft. The presentation will give an overview of the Attitude and Orbit Control System on SMART-1. In particular, the presentation will focus on the constraints and drivers imposed by the electric propulsion engine. Special attention will also be given to the elaborate on-board autonomy as well as the extensive use of auto-generated code in the development of the on-board software.

04-2. ONBOARD THRUST DIRECTION COMPUTATION ALGORITHM FOR LOW-THRUST MINIMUM-TIME TRANSFERS

J. Fourcade
CNES, France

Abstract
Not available

04-3. MERCURY MISSION WITH USE OF SOLAR ELECTRIC PROPULSION

Gennadiy Fedotov, Mikhail Konstantinov
Moscow Aviation Institute, Russia.

Abstract

Transport opportunities of delivery of a spacecraft to Mercury with the use of launcher "Soyuz", chemical upper stage "Fregat" and solar electric propulsion upper stage (nominal electric power 6.75 kW) is analysed. The outcomes of research are:

- At use of stationary plasma thruster (specific impulse 2000 s) it's possible to deliver into Mercury's vicinity the spacecraft with mass about 800 kg at transfer duration 785 day;
- Use of ionic thruster (3000 s) allows to increase this mass on 250 kg at transfer duration 1050 day;
- Using of Venus swingby gives additional increment of mass on 150 kg.

04-4. ON OPTIMIZATION OF TRANSFERS WITH A CONSTRAINED THRUST DIRECTION

Alexander A. Sukhanov,
Space Research Institute, Russia

Abstract

A low thrust transfer is considered. It is assumed that the thrust direction is subject to a constraint. This constraint may be caused by specific features of the spacecraft stabilization mode and attitude control system and in a general case is a function of time and the spacecraft state vector. Mathematically the constraint is given by a manifold, which the thrust direction belongs to. It is shown that the optimal thrust is directed along the projection of the Lawden's primer vector onto the manifold. Both limited power and constant exhaust velocity cases are considered. Some examples of the constraints are given. The transporting trajectory method is applied to the case of the constrained thrust direction; this method also gives a sufficient condition of the possibility of transfer with a specified constraint.

04-5. OPTIMIZATION METHOD OF LOW THRUST TRANSFER FROM ELLIPTICAL ORBIT INTO NONCOPLANAR CIRCULAR ORBIT

Mikhail Konstantinov
Moscow Aviation Institute, Russia

Abstract

The method of optimization of multirevolution trajectories of transfer from elliptical orbit into noncoplanar circular orbit is developed. The basic idea is use of the some model problem of optimal control. This model is chosen so, that solution of model optimization problem does not have any considerable difficulties. This solution is considered base for determination of the optimal solution of a common problem. The basic advantages of a developed method are:

An absence of a problem of convergence of iterative procedures of the solution;

Representation of the solution of problem of an optimal control as synthesis.

Session 5
ORBIT DESIGN, MISSION ANALYSIS
10:20-12:00

05-1. ORBIT DESIGN AND IMPLEMENTATION OF THE INTEGRAL MISSION

Roberta Mugellesi-Dow, Guy Janin
ESOC, Germany
Natan Eismont
IKI, Russia

Abstract

After having recalled characteristics of orbits for space astronomical observatories and the particular advantage of selecting synchronous orbits, this paper highlights the novel orbital aspects of the INTEGRAL mission from the Flight Dynamics point of view: launch on a 72d orbit using a Russian Proton rocket equipped with the upper stage Block DM, the special preparation undertaken in ESOC to counter-act non-nominal performance of the launcher upper stage, and the orbit manoeuvres sequence dependency on various constraints. The paper outlines the operational and technical constraints that had to be respected in the definition of the orbit design and during the implementation, and the major orbital activities that were performed during the launch and early orbit phase.

05-2. DESIGN OF HIGH ELLIPTICAL AND DISTANT EARTH CONNECTED TRAJECTORIES

N. Eismont, V. Khrapchenkov,
Space Research Institute, Russia
G. Janin, R. Mugellesi-Dow
European Space Operations Centre, Germany,

Abstract

Not available

05-3. THE CELESTA PROJECT: ASTROMETRICAL SATELLITE OF SMALL-SIZE WITH OPTICAL ARCMETER-INTERFEROMETER

A.A.Boyarchuk, A.V.Bagrov,
Institute of Astronomy of the Russian Academy of Sciences, Russia,
K.M.Pichkhadze, V.K.Sysoev,
Lavochkin Science & Industry Corporation, Russia

Abstract

A technical design of the OSIRIS two-based optical space interferometer is based on the carbon-fibre technology and on the newest Russian achievements in laser metrology and light sensors. The whole instrument was designed as a payload to the Russian Segment of the ISS and it consists of two blokes that will be brought to the ISS by transport spacecraft "Progress" and installed there by astronauts. Short-live devices of the OSIRIS interferometer - light sensor and metrological laser - are replaceable for fast repairs in the open space conditions. Due to the carbon-fibre strongly constructed case and to the absence of reserved devices the total mass of the OSIRIS interferometer will not exceed 250 kg.

The two-based interferometer OSIRIS consists of four off-axis telescopes, four adjustable delay lines, and two light sensors of the MAMA-type and metrological system. Besides that every telescope will have its own guide for precision pointing to the target stars. The whole instrument will use its own independent to the ISS pointing and tracking systems. It will be mounted to the RS ISS by magnetic controlled suspension device.

The OSIRIS Project was admitted to the Russian National Space Program as a payload to the RS ISS at the promoted stage, and it might be launched at 2002-2003 years.

05-4. COMMUNICATIONS SATELLITE SYSTEM BY TWO-TROJAN AND ONE EQUILIBRIUM ORBIT SATELLITES OF THE EARTH-MOON SYSTEM

Sanguk Lee, Jae Hoon Kim, Seong Pal Lee
Communications Satellite Development Center, ETRI, Korea

Abstract

In this paper, we suggest communications satellite system placed in three Lagrange points, L3, L4, and L5, of the restricted three-body problem of Earth-Moon system. Generally, geostationary satellites are used for communications so far. Recently, LEO satellite constellation is another choice of communications system. The proposed system which is alternatives of limited geostationary orbit resources, has some weak points such as long distance from the Earth, much cost to launch satellite, long delay time, required more power, and so on. It has good points like less efforts(fuel) for station keeping, less eclipses, etc. In this paper, some analyses about the proposed system such as characteristics of orbits, eclipses, perturbations, link requirements for communications, pointing accuracy, ground station operation concept, possible services to be provided, and so on will be presented.

05-5. CONCURRENT PROCESSES WITHIN PRELIMINARY SPACECRAFT DESIGN: AN AUTONOMOUS DECISIONAL SUPPORT BASED ON GENETIC ALGORITHMS AND ANALYTIC HIERARCHICAL PROCESS

M.Lavagna, A.E.Finzi
Dipartimento di Ingegneria Aerospaziale, Italy

Abstract

This paper proposes a method to support decisions to be taken within a concurrent approach for the space system preliminary design: the defined architecture is based on a Multi-Criteria Decision Making approach mixed with methodologies coming from the Approximate Reasoning domain. The method here presented is focused on saving analysts' time and effort by addressing the decisions they have to make during the preliminary design process to solve inconsistency and bottlenecks risen from the parallel design of several subsystems. Moreover, different configurations can be considered at a time ranked according to a pre-selected criteria vector. From a theoretical point of view, revisited Genetic Algorithms are applied, within each single subsystem design domain, in order to obtain a non-dominated solution set to be considered for solving conflicting design at system level; the Analytical Hierarchical Process - supported by dedicated blocks implemented by the Fuzzy Logic approach has been selected as the fittest tool to simulate the causal relationships between variables and objectives, normally prerogative of the analysts' experience in the spacecraft design domain, within the system level point of view. Simulations showed the ability of the algorithm to find conflicts and suggest a set of subsystem parameters to be tuned to converge - consistently with a user defined cost

functions vectors - to a final spacecraft configuration; the tool runs in real-time with the on-going space system design process, in order to support the team leader in making decisions. A comparison with a completely transparent optimization process, implemented by MOGA, highlighted the capability of the proposed approach to move towards the final Pareto front solution.

Session 6
Deep Space Missions
13:30-15:30

06-1. NAVIGATION FOR A 2009 NETLANDER MISSION
Stephanie Delavault, Laurent Francillout, Denis Carbonne,
CNES, France

Abstract

The challenging phase of a NETLANDER-like mission is the successive release of several Landers to the Martian soil. From a navigation point of view, this deployment requires a high accuracy level for the Netlander entry trajectory with only few days of tracking schedule and a long free-flying phase. This paper presents covariance analyses over the complete Earth to Mars cruise and Mars approach phases of such a mission performed to determine the impact on navigation performance of parameters such as the addition of DDOR measurements, tracking data schedule, maneuver execution errors: Conclusions are drawn on navigation needs and an assessment is made of the robustness of navigation performance for the Netlander deployment phase.

06-2. DESCRIPTION OF THE RENDEZVOUS EXPERIMENT DESIGNED FOR 2007 MARS PREMIER MISSION
M.Delpech, J-B.Dubois,
CNES, France,
J.E.Riedel, J.R.Guinn
JPL, USA

Abstract

The Mars Premier mission that was to be flown in 2007 by CNES in cooperation with NASA/JPL included a rendezvous experiment to be performed in Mars orbit to validate key technologies applicable to a Sample Return mission. The paper presents an overview of this experiment outlining mission design, system implementation, operational aspects and validation work achieved before the program was stopped in October 2002.

06-3. ORBIT SELECTION, NAVIGATION AND MANEUVERS BEFORE THE LANDING ON THE PHOBOS SURFACE FOR PHOBOS SAMPLE RETURN PROJECT

Tuchin A.G., Akim E.L., Botkin A.B., Stepaniants V.A.
Keldysh Institute of Applied Mathematics, Russia
Ruzskiy E.G.,
Lavochkin Association, Russia

Abstract

The goal of the Phobos sample return project is Phobos soil delivery to the Earth. This paper describes the Mars satellite phase of the mission. The task of this phase is to lead the spacecraft to specific area located at altitude 40-60 km above the Phobos surface with the accuracy satisfied to autonomous lending system requires. The questions of ballistics, navigation and flight control are considered. Two orbits are used during the Phobos approach phase - an observation orbit and a quasi-synchronous orbit from which landing to the Phobos surface is performed.

06-4. OPTIMAL TRANSFER FROM EARTH SATELLITE ORBIT TO MARS SATELLITE ORBIT USING ELECTRIC PROPULSION SYSTEM AT THE CRUISE PHASE

G.S. Zaslavskiy, V.G. Zharov, A.V. Chernov
KIAM, Russia

Abstract

The optimal spacecraft flight to Mars satellite orbit with using electric propulsion system is studied. The effect of the attractions of the Sun, the Moon and the Solar system planets on the spacecraft motion in during of the all flight time is taken into account.

06-5. THE DEVELOPMENT AND JUSTIFICATION OF THE SPACECRAFT FLIGHT SCHEMES FOR THE MARTIAN MANNED EXPEDITION

N.M. Ivanov, Yu.F. Kolyuka
Mission Control Center, Russia

The results of the work for the construction and justification of the flight schemes for the Martian manned expedition that was done within the frame of the ISTC grant are given. This expedition implies round transfer Earth – Mars – Earth as well as staying the manned vehicle on near-to-Mars orbit and landing of astronauts to the Mars surface.

The flight schemes for two conceptual variants of the Expedition – two-vehicles scheme variant (including the flights of manned and cargo ships) and one-ship scheme variant were developed and analyzed.

The calculations of the mission schemes were based on the special methods and software tools that allow considering both the low-thrust and large-thrust flights. The short description of these methods is represented.

06-6. GROUND ANTENNAS OF RUSSIAN DEEP SPACE MISSIONS: HISTORY, STATE, PERSPECTIVES

E.P. Molotov, I. E. Molotov
Russian Institute of Space Device Engineering, Russia

Abstract

Russian Deep Space Network was based on three large antennas - RT-70 in Evpatoria and Ussuriysk, and RT-64 in Bear Lakes. Russian deep space and high-apogee missions were controlled with these dishes. The antennas were temporary stopped after the loss of the Mars-96. The operations of Evpatoria and Bear Lakes were renewed for radio astronomy goals. Both antennas participate in VLBI observations and radar researches of space debris under LFVN project. The limited financing of Ussuriysk RT-70 was continued recently under preparing the Phobos sample return mission. The partners interested in joint usage of these antennas are sought.

Session 7
Atmospheric Entry
15:50-17:30

07-1. COMPUTATIONAL MODEL OF THE EARTH DISTURBED ATMOSPHERE: ADVANCED VERSION AND TEST RESULTS OR BALLISTIC REENTRY TRAJECTORIES

Yu.G.Sikharulidze, A.N.Korchagin,
Keldysh Institute of Applied Mathematics RAS, Russia

Abstract

Not available

07-2. ATMOSPHERIC DENSITY CORRECTIONUSING REAL ORBITAL DATA

Andrey Nazarenko,
Space Observation Center, Russia
Vasiliy Yurasov,
Space Research Center "Kosmos", Russia

Abstract

Perspective direction of an accuracy increasing of satellite orbit determination and prediction for low earth orbit (LEO) satellites is the organization of the upper atmosphere monitoring, i.e. analog of a weather service in the lower atmosphere. Our

idea of the upper atmosphere monitoring is based on the usage of the available satellite atmospheric drag data on catalogued LEO satellites. These data are obtained as a result of regular satellite observations and updated some times per day.

The variations of atmospheric density for GOST-25645.115-84 model were estimated over 9 month time interval. For these purpose real orbital data for several hundred space objects with perigee heights below 600 km were accumulated and processed. The effectiveness of density correction under various atmospheric conditions was estimated.

The monitoring of the upper atmosphere density variations would allow to increase the prediction accuracy of LEO satellites motion and to obtain more accurate atmospheric density estimates without development a new model.

07-3. METHODS AND RESULTS OF DESIGNING AND OPERATIONAL FLIGHT DYNAMIC TASKS OF SPACECRAFT RETURN TO THE EARTH

V.A. Udaloy, N.M. Ivanov, S.I. Kudryavtsev, A.A Savchenko
Mission Control Center

The operational flight dynamics support tasks for the spacecraft controlled from the Russian Mission Control Center are considered. A modern set of tasks accomplished in the flight dynamics support of the Soyuz TM and Progress M transport vehicles reentry is shown. Specific features of the Soyuz TMA transport vehicle reentry support are considered.

The Mission Control Center interface with other organizations is shown. Methods of solution of reentry flight dynamic support tasks are briefly described. Examples of reentry support activities in nominal and contingency situations are given.

The examples of the Mission Control Center participation in international projects, both in the field of operational flight support and designning investigations, are shown.

07-4. THE GUIDE ALGORITHM FOR AN ATMOSPHERIC RE-ENTRY VEHICLE

Yu. N. Kaluzhskikh
KIAM, KIA Systems, Russia

Abstract

In this article the guide algorithm for an atmospheric re-entry vehicle is described. It is considered a phase of a re-entry trajectory at the altitude range of 100 to 10 km. The guide algorithm has two parts. The first one is to generate an initial reference bank angle sequence to get a re-entry vehicle at a prescribed point. The second one is to correct the initial reference bank angle sequence in order to reduce the influence of disturbed atmosphere during re-entry. Results of a mathematical simulation are presented in this article too. We have considered 3DOF trajectories

with simplified description of the bank angle change. Simulation results confirm that the accuracy of the developed re-entry algorithm is about 0.7 km.

18 June 2003, Wednesday

Session 8
Attitude Dynamics, Estimation, Control
08:20-10:00

08-1. PRECISE CALIBRATION OF XMM-NEWTON AND INTEGRAL THRUSTERS FROM ORBIT MANOEUVRES AND REACTION WHEEL BIASINGS

G.Gienger,
ESA, Germany,
J.B.Palmer
LogicaCMG, Germany

Abstract

Each observatory is equipped with 2x4 20N thrusters for orbit-manoeuvres and momentum-dumps. Orbit manoeuvres are performed with all 4 prime thrusters, each canted 12 degree w.r.t. the satellite x-axis.

Attitude-control attempts to reduce the cumulative angular momentum change from all 4 thrusters to zero via off-modulation, hence one can set up a linear system of 4 equations for the 4 thruster calibration factors.

For the largest orbit-manoeuvres, cumulative angular momentum for each individual thruster was of order (+25000, +110000, 105000) Nms. Since total cumulative angular momentum is zeroed to an accuracy of 1 Nms, the ratios of the 4 calibration factors can thus be determined to 1:20000. The relative accu-racy of the sum of the 4 calibration factors is approximately the relative accuracy of the x-component of the Delta-v as observed by orbit determination.

08-2. INVESTIGATION OF MICROGRAVITY ENVIRONMENT IN ISS SERVICE MODULE

E.V. Babkin, M.Yu.Beliaev,
RSC Energia, Russia,
N.I.Efimov, D.A.Zavalishin, V.V.Sazonov
Keldysh Institute of Applied Mathematics RAS, Russia

Abstract

We present the results of determination of residual accelerations in Russian Segment of ISS. A quasi-steady acceleration component was determined using telemetry information about the station attitude motion. Basing on the information,

we reconstruct the station motion and calculate the acceleration at any given point on its board as a function of time. We tested this approach using measurements of US low frequency triaxial accelerometer MAMS and obtained a good agreement. A vibrational acceleration component was measured by several three-axis accelerometers IMU-128. They measure accelerations with magnitude more then 0.001 m/s in the frequency range up to 20 Hz.

08-3. XMM-NEWTON AND INTEGRAL ON-GROUND ATTITUDE RECONSTRUCTION PERFORMANCE ASSESSMENT

M. J. Tuttlebee
Science Systems Space Ltd, Germany

Abstract

The Attitude Determination and Control Sub-System, which is part of the ESOC On-ground Flight Dynamics System, provides tools to perform attitude determination for on-line mission re-planning at the Mission Operations Centre and attitude history products for the Science Operations Centres.

08-4. SHORT PLANNING RESPONSE TIME AND HIGH FLEXIBILITY OF THE ASTRONOMY/AERONOMY SATELLITE ODIN

E. Vinterhav
Swedish Space Corporation, Sweden

Abstract

The Swedish small satellite Odin has an extremely short response time has been built into its operations cycle. Odin is a 3-axis stabilized, high pointing accuracy, sub millimeter, space observatory. The operation cycle is defined as: receiving user demands, planning and generation of tele-commands to implement coordinated execution of platform and payload activities, reconstruction of attitude and orbit trajectories, feedback to users of payload status and delivery of data. A small efficient team together with easily accessible, script based, software based on COTS components facilitates in rapidly meeting new demands on the planning and attitude reconstruction from the users.

Session 9
Flight Dynamics Software
10:20-12:00

09-1. IMPROVEMENTS IN ROUTINE ORBIT DETERMINATION AND ORBIT PREDICTION ACCURACY FOR ENVISAT
Dirk Kuijper
Logica plc based at the European Space Operation Center (ESOC), Germany

Abstract
Not available

09-2. QUARTZ ++, ASTRIUM EVOLUTIVE FLIGHT DYNAMICS SYSTEM
F. Raballand, J.L Gonnaud
ASTRIUM, France

Abstract
Based on its large experience, ASTRIUM has developed a new generation Flight Dynamics System:

QUARTZ++. This new package is designed for station keeping operations, transfer preparation and LEOP operations for GEO spacecraft.

QUARTZ++ is currently used by INTELSAT for LEOP operations and for the routine control of the INTELSAT fleet.

QUARTZ++ will be soon implemented in INMARSAT control centre for the Flight Dynamics command during transfer and on station on inclined orbit of the three INMARSAT 4 spacecraft, ASTRIUM Eurostar 3000 class satellites.

QUARTZ++, in addition to services for autonomous on ground orbit control, will soon be improved to cover Low Earth Orbit missions including formation-flying control.

09-3. COMPUTER-BASED INSTRUCTION AND REFERENCE DOCUMENTATION SYSTEM FOR THE ORBIT DETERMINATION PROGRAM
Gerald R. Hintz, Mark Ryne, Michael Watkins, Maureen Kenney, David Overoye
Jet Propulsion Laboratory, USA

Abstract
The Orbit Determination Program set has been used at the Jet Propulsion Laboratory for nearly half a century to enable precision navigation of interplanetary and earth-orbiting missions and to support a myriad of scientific investigations. Executing this software package successfully is a challenging task for experienced personnel and a daunting one for junior navigators. The effort described in this paper

provides a computer-based, web-enabled instructional and reference tool to aid both experienced and beginning personnel in the art of doing orbit determination with this software.

09-4. FOCUS: A NEW CONCEPT ON FLIGHT DYNAMICS OPERATIONS
Miguel Angel Molina Cobos
Flight Engineering Business Unit Director, Spain

Abstract

GMV has developed an internal project, called focus, which is aimed at producing a new generation of Flight Dynamics systems by exploiting all GMV's past and present experience in the domain and all the current baseline of GMV's Flight Dynamics systems. Project focus came through successful requirements definition during the first half of 1999 and the development phase started in August 1999. focus has very ambitious goals in mind, in particular the development of a truly generic operational FDS for all type of satellite missions (including GEO, LEOP, LEO, satellite formations, constellations, etc.) to be commercialised as a COTS product.

Focus is now progressing in a phased approach and the first member of this family has been oriented to GEO satellites. In this context, a sub-project named focusGEO has been conceived to produce a first version of focus including all fundamental features of the final system (MMI, graphics, data access, on-line help, process manager, events logging, automation), in order to provide a new generation Flight Dynamics product for geostationary satellites. This focusGEO version is now available and operational at HISPASAT and EUTELSAT.

SESSION 10
Attitude Dynamics, Estimation, Control
13:30-15:30

10-1. AN ON-BOARD ALGORITHM FOR SLEW MANEUVERS WHICH AUTONOMOUSLY AVOID A FORBIDDEN DIRECTION
Karlheinz Spindler
Fachhochschule Wiesbaden, Germany

Abstract

We consider the problem of slewing a rigid spacecraft (typically a space telescope) from rest to rest between prescribed attitudes while avoiding a forbidden direction during the slew. Using methods from differential geometric control theory, we derive a control law which minimizes a cost functional penalizing both high angular velocities and proximity to the forbidden direction and which turns out to be very suitable for implementation in the on-board software.

10-2. ATTITUDE DYNAMICS AND CONTROL OF BIFOCAL RELAY MIRROR SPACECRAFT WITH FAST STEERING MIRRORS

Marcello Romano, Brij N. Agrawal
Spacecraft Research and Design Center, USA

Abstract

This paper presents the attitude dynamics and control of the bifocal relay mirror spacecraft. The spacecraft consists of single axis gimbaled receiver and transmitter telescopes with 1.64 m diameter primary mirrors and fast steering mirrors for fine beam control. The transmitter telescope has a majority of the spacecraft bus subsystems including attitude control sensors and actuators. The attitude control system consists of either Reaction Wheels or Variable Speed Control Moment Gyros, star trackers, gyros, sun sensors, magnetometers and magnetic rods. Feed-forward control and quaternion formulation are used. Kalman filter is used to update the rate gyros biases and the attitude parameters.

10-3. TARGET POINTING OF THE BIRD SPACECRAFTVIA GROUND IN THE LOOP ATTITUDE CONTROL

Manfred Schneller
German Space Operations Center, Germany

Abstract

BIRD, a Bi-spectral Infra-Red Detector is a micro-satellite mission for earth observation. It has been launched on Oct. 22, 2001 on a PSLV-C3 from Sriharikota, India. Nominal operations include attitude maneuvers to switch attitude from sun pointing for battery charging to target pointing for data-takes and for downlinking of high rate data. Since launch attitude determination, prediction and attitude maneuver design is performed on-ground filling in for an incomplete onboard attitude control system not yet implemented to its full extent. Between launch and Apr. 2, 2003 over 250 targets on ground have been successfully recorded.

10-4. THE ESA PROBA MISSION WITH SOME UNIQUE FLIGHT DYNAMICS FEATURES

Mats Rosengren,
European Space Operations Centre, Germany

Abstract

The name PROBA stands for PRoject of OnBoard Autonomy and the main purpose of the PROBA spacecraft is to test and demonstrate some autonomy concepts. In addition it carries new space equipment for tests/demonstration. The PROBA spacecraft was brought into a sun-synchronous orbit with a local time of descending node of 10:30 on 2001/10/22 by an Indian PSLV launch vehicle taking

off from the SHAR centre on the Sriharikota island (south of India). Its orbit is slightly eccentric with an altitude varying between 570 and 670 km.

10-5. COROT INSTRUMENT ANGLE ERROR MEASUREMENT USED IN AOCS CONTROL LOOP

Stéphane BERRIVIN (*), Vincent COSTES
CNES, France
Michel AUVERGNE
DASGAL, France
Patrick LEVACHER
LAM, France

Abstract
Not available

19 June 2003, Thursday

Session 11
Formation Flying, Constellation, Maneuvers Design, Guidance, Control
08:20-10:00

11-1. OPTIMAL SMALL FORMATION FLYING INITIALIZATION IN CIRCULAR ORBIT

Arnaud Boutonnet, CNES, France
Andrei Baranov, KIA Systems
Vincent Martinot, Alcatel Space
Benedicte Escudier, ENSAE-Supaero
Joseph Noailles, LIMA-Enseeiht

Abstract

Basically the formation initialization task is a rendezvous. We begin by showing it can be replaced by a transfer task.

Considering an injection impulse from the launcher whose amplitude is free, we focus on the optimization of this maneuver, the formation phase angle and the transfer maneuvers. Two methods which allow to minimize the propellant consumption are presented: a one impulse simple strategy and a two impulse optimal strategy. We obtain analytical and optimal guidance laws from a geometrical approach combined with constraints given by the Primer Vector necessary conditions of optimality.

The collision risk is assessed with an analytical distances analysis. Then different parameters are optimized with respect to the minimum distance without changing the propellant consumption.

11-2. ORBIT ANALYSIS FOR AN ENVIRONMENTAL DATA COLLECTING CONSTELLATION

Pawel Rozenfeld, Valcir Orlando, Wilson Yamaguti,
INPE, Brazil

Abstract

The existing INPE's Environmental Data Collecting System is composed by two small data collecting satellites (SCD1 and SCD2), inserted in low altitude, 25 degrees inclination orbits; a remote sensing satellite (CBERS1), positioned in a low altitude 98.4 degrees inclination orbit; two Data receiving Stations (Cuiaba and Alcantara); about 600 Data Collecting Platforms - DCP, covering a large range of applications, scattered over Brazilian territory; and a centralized Data Processing and Distribution Facility. Since the launch of the first satellite until now, the Data Collecting System experienced a significant growing in terms of user community, and in terms of application diversity. Thinking in terms of replacing the current satellites and of improving the system performance, a new data collecting constellation is studied in this work. The study is basically concentrated in the determination of the constellation orbits and number of satellites, which could assure satisfactory coverage and time regularity characteristic for a region which contains, at most, all the South America territory, and, of course, the symmetric northern hemisphere region. The obtained results are presented and extensively discussed.

11-3. MANEUVER FREQUENCY ANALYSIS FOR LEO FORMATIONS

Uwe Feucht, Christian Arbinger, Michael Kirschner
German Space Operations Center, Germany

Abstract

Main drivers for the number and size of orbit control maneuvers for LEO satellite formations are the payload requirements and, as learned from GRACE, the impact of the attitude variation due to the aerodynamic drag.

To fulfill these requirements the orbit maneuver size and frequency is the main parameter for the compensation for the aerodynamic perturbations. GRACE experience shows that differences from the expected orbit decay in altitudes around 500 km in a short-term range are mainly caused by attitude changes (for mid- and long-term planning also the solar activity variations must be taken into account).

11-4. ATV DEORBITATION STRATEGY

Laurent Francillout, Pascal Desmazeaux
CNES, France

Abstract

In December 1998, the ESA council decided to locate the Automated Transfer vehicle Control Center (ATV-CC) at CNES/Toulouse. Although ATV is an

Automated vehicle, it relies on ground support in particular during deorbitation phase. So the Flight Dynamics subsystem is in charge of the ATV re-entry and shall guarantee for each mission configuration (various range of altitude, and phasing) a boundary impact zone with an adequate level of confidence. The purpose of this paper is to present the ATV scenario. The analysis has to estimate the minimum required DV budget allocation to perform deorbitation in safe conditions and to evaluate the dispersions around nominal trajectories.

11-5. A SOFTWARE FOR RENDEZVOUS BETWEEN NEAR-CIRCULAR ORBITS WITH LARGE INITIAL ASCENDING NODE DIFFERENCE

Pierre LABOURDETTE
CNES, France
Andrei BARANOV
KIAM/KIAS, Russia

Several missions perform rendezvous between near-circular and no coplanar orbits (Mars Sample Return, Constellations). Maneuvers cost must be optimized taking into account the natural drift of the orbit plane thanks to the second zonal harmonic coefficient of the gravity field. Additional fuel-savings can be achieved thanks to small inclination corrections that contribute to the orbit plane drift. The optimization problem is difficult to be solved with general non-linear optimization algorithm: non-convergence problem raises when tuning at the same time nodal drift and in-plane phase angle correction. This is due to very long duration dedicated to rendezvous (several hundreds of vehicle revolutions separate two maneuver cycles). We will demonstrate, in the paper, how a simple analytical approach copes with these problems. Tuning mainly the semi-major axis by the mean of simple equations allows estimating the intermediate drifting orbit in order to catch-up at the same time nodal and in-plane phase angles. Examples will be described showing advantages of the method.

Session 12
Orbit Determination
10:20-12:00

12-1. IMPROVEMENT OF ORBIT DETERMINATION ACCURACY OF SELENE BY ESTIMATING THE LUNAR GRAVITY MODEL DURING ITS OPERATION PHASE

Mina Ogawa, Masao Hirota, Kazuaki Nonaka, Yoshio Morooka, Shigehiro Mori, Mikio Sawabe
NASDA, Japan

Abstract

SELENE is a Japanese lunar explorer scheduled to be launched in FY2005. RSAT mission of SELENE is to perform satellite-to-satellite Doppler measurement over almost the entire moon surface. RSAT team is going to improve the lunar gravity model using data of two months or more. The results of preliminary analysis showed that the orbit determination accuracy can be improved by the lunar gravity model estimated using SELENE data of shorter period though the data has little effect on improving the model. This paper presents the outline of RSAT mission, and the results of the analysis.

12-2. OPTICAL NAVIGATION PERFORMANCE DURING INTERPLANETARY CRUISE

Laurent Chausson
Communication & Systemes, France
Stephanie Delavault
CNES, France

Abstract

During the interplanetary flight of a probe, optical measurements of celestial bodies (such as asteroids) make possible autonomous navigation. This cost-effective technique was tested in 1999 by Deep-Space-One. Asteroids are selected according to various criteria such as magnitude, distance and star density. An additional criterion is the spatial configuration that optimizes the orbit determination accuracy. The resulting error ellipsoids are computed using the CNES covariance analysis tool "Eperon", taking into account several error sources (data noise, center finding, asteroids ephemeris, non-gravitational forces, etc), for the Earth-to-Mars transfer of Mars-Premier-2007. This study is performed jointly by CS and CNES.

12-3. ASSESSING ORBIT DETERMINATION THROUGH ONE WAY DOPPLER SIGNALS

Helio Koiti Kuga, Valcir Orlando,
INPE, Brazil

Abstract

In a search for cheap, easy, and still fairly reliable system for satellite control, an economical way of yielding orbit information is to measure the Doppler shift suffered by the signal transmitted by the satellite, commonly named one-way Doppler measurements. This paper gives an analysis of such Doppler based orbit determination which will be used in the French Brazilian Micro-satellite (FBM) satellite under development. The ground segment consists basically of a control center and a single tracking station located at Natal, Northeast of Brazil. Requeriments for orbit accuracy coming from the scientific community is rather loose, so that the main requirements are due to operations of tracking and scheduling of the control center. Initially a covariance analysis is shown, which depicts the accuracy achievable by the orbit determination based solely on one-way Doppler measurements from a single tracking station. Afterwards, we use one-way Doppler measurements taken from the SCD1 Brazilian satellite, a live flying satellite with similar orbit pattern. These measurements presented problems typical of the ones expected during the FBM mission. Orbit determinations are performed using such set of data to show the errors with respect to the reference orbit. At the end some conclusions and recommendations are drawn.

12-4. NASDA PRECISE ORBIT DETERMINATION EXPERIMENT OF ADEOS-II

Maki Maeda
NASDA, Japan

Abstract

NASDA have started study of precise orbit determination since 1994. In 1996, we succeeded in the estimation of ADEOS trajectory less than 1-meter accuracy as a research basis. After that, NASDA started development of precise orbit determination system which treat on-board GPS, ground GPS and SLR data. About the GPS satellite orbit, it could be determined with less than 50cm accuracy using ground GPS data. After the launch of ADEOS-II on Dec.14th, we started to determine orbit of ADEOS-II, using on-board GPS (only L1) and SLR data. It will be determined with the less than 5 meters as a comparison result of GPS and SLR.

12-5. SOLVING OF A PROBLEM OF PRECISE NAVIGATION BINDING OF SCIENTIFIC MEASUREMENTS IN THE "METEOR - 3M/SAGE-3" PROJECT IN REAL CONDITIONS OF SPACECRAFT FLIGHT

Yu.F.Kolyuka, T.I.Afanasieva, T.A.Gridchina
Mission Control Center, Russia

Abstract

Carrying out and processing of measurements fulfilled with the help of instrument “Sage-3” equipment established onboard the spacecraft "Meteor - 3M" which was started in December 2002, provides maintenance enough exact knowledge of both the S/C position and time at the moments of these measurements performance. For the solving of a problem of high precision navigation binding Sage-3 experiment it was planned to use the onboard GPS/Glonass equipment for satellite navigation. However, this equipment established on S/C "Meteor - 3M", appeared to be disabled.

The presented work is devoted to revealing of special approaches and development of additional ways to achieve the accuracy what would turn to be of good precision for "Sage-3" experiment operation and for S/C "Meteor - 3M" orbit prediction in conditions of absence of onboard GPS/Glonass equipment measurements, but only on the base of the regular ground-tracking measuring means stipulated by the given project for the S/C orbit control.

The results of the S/C orbit determination, that were obtained with the help of the specified approaches and ways are listed. These results allow to estimate real accuracy of S/C "Meteor - 3M" orbit knowledge.

Session 13
Orbit Determination
13:30-15:30

13-1. OPTICAL MEASUREMENT FOR PARALLEL ORBIT DETERMINATION OF NEAR GEOSYNCHRONOUS OBJECTS

Hiroaki Umehara, Masaaki Takahashi, Kazuhiro Kimura
Kashima Space Research Center, Japan

Abstract

Many orbits of the respective objects should be observed and determined quickly and accurately for full utilization of finite orbital resources such as the geostationary orbit. For the purpose, optical observation has an important role because it is applicable for objects with unknown frequencies transmitted. The U.S. and Russia have taken the initiative in surveillance. In Japan, high-resolution telescopes were built in order to detect small unknown objects. Much unknown debris

will be discovered soon. An international concern is the operating expense associated with the detection and the orbit determination.

Our working Kashima Space Research Center in CRL built an optical observation facility in 1998.

The telescope is an epsilon Newtonian reflector.

13-2. REAL-TIME TRAJECTORY ESTIMATION EXPERIMENTS WITH DRTS

Seiji Katagiri, Mina Ogawa, Mikio Sawabe, Masao Hirota, Ken Nakajima, Manabu Hotta
NASDA, Japan

Abstract

The Real Time Trajectory Estimation Program (RTEP) is NASDA's system for estimating a satellite's trajectory and thrust acceleration based on the Kalman filter during the apogee engine firing (AEF). RTEP has been used experimentally during the AEF of, ETS-VI (1994) and COMETS (1998). On September 2002, RTEP was used operationally for four AEFs of DRTS (Data Relay Test Satellite). This paper presents the overview of the RTEP, operation configuration, the detailed results of the operations concerning the AEF phase of DRTS, and the future plan to improve the performance of the RTEP.

13-3. SPECIFIC FEATURES OF TRAJECTORY AND NAVIGATIONAL FLIGHT SUPPORT FOR INTERNATIONAL SPACE STATION

V.N. Zhukov, E.K. Melnikov
MCC, Russia

The main trends and tasks for flight dynamics and ballistic and navigational support of ISS are covered. Also represented are: the main tasks for the ISS pointing, being solved at MCC-M in the course of maintaining the Station flight altitude strategy, specifics of MCC-M to MCC-H interaction in the process of space debris avoidance tasks.

Session 14
Attitude Dynamics, Estimation,Control
15:50-17:30

14-1. ANALYTICAL ATTITUDE PROPAGATION OF SPIN STABILIZED EARTH ARTIFICIAL SATELLITES

Maria Cecilia F. P. S. Zanardi
UNESP, Brazil,
Isaura Martinez Puentes Quirelli
UNESP, Brazil,
Helio Koiti Kuga
INPE, Brazil

Abstract

An analytical approach for spin-stabilized satellites attitude propagation is presented, considering the influence of the residual magnetic torque and eddy currents torque. It is assumed the inclined dipole model for the Earth?s magnetic field and the method of averaging such torques, over each orbital period, is applied to obtain the components of the torques in the satellite body frame reference system. The inclusion of these torques on the rotational motion differential equations of spin stabilized satellites yields the conditions to derive an analytical solution. The solution shows that the eddy currents torques causes an exponential decay of the angular velocity magnitude and the coupled effect of both torques produces a precession on the spin axis. Numerical simulations performed with data of the Brazilian satellites (SCD1 and SCD2) show the agreement between the analytical solution and the actual satellite behaviour.

14-2. ESTIMATING THE INERTIA TENSOR OF THE INTERNATIONAL SPACE STATION ON THE BASE OF TELEMETRY INFORMATION

M.Yu.Beliaev, V.M.Stazhkov, Yu.A.Banit
RSC Energia, Russia,
N.I.Efimov, V.V.Sazonov
Keldysh Institute of Applied Mathematics RAS, Russia

Abstract

We present the method and results of estimating the inertia tensor of ISS on the base of the telemetry information about its orientation and the total angular momentum of gyrodines. At first, we reconstruct the station attitude motion. Then such a reconstruction is used in the linear differential equations, which describe the variation of the angular momentum of gyrodines during the motion and depend upon inertia tensor components. We estimates these quantities from the condition of the

best approximation of angular momentum measurements by sulutions of those equations using the least squares method.

14-3. ORBIT AND ATTITUDE DETERMINATIONS OF KOMPSAT-1 USING SUN SENSOR AND MAGNETOMETER DATA

Sanguk LEE, Kyoung Min ROH, Jae Hoon KIM, Seong Pal LEE
Communications Satellite Development Center, Korea

Abstract

KOrean Multi-Purpose SATellite-1(KOMPSAT-1) which is remote sensing satellite had been launched in December 1999 and has been being operated normally by Mission Control Element(MCE), which was developed by Electronics and Telecommunications Research Institute(ETRI). For LEOP or contingency operations, orbit determination and attitude determination by using data from onboard magnetometers and sun sensors are presented in this paper. Firstly, orbit determination of KOMPSAT-1 using measured data by magnetometers and conical earth sensors during normal operation phase is carried out and it is verified by GPS data gathered from onboard. Secondly, attitude determination of KOMPSAT-1 using measured data by magnetometers and GPS during normal operation phase is carried out and the result is verified by attitude data from the satellite. Finally, The orbit determination and the attitude determination are carried out simultaneously using measured data by magnetometers and sun sensors during sun pointing operation mode, which is very close to contingency operation mode. The results are verified by GPS data.

14-4. LESSONS LEARNED IN THE DEVELOPMENT, BUILDING AND USAGE OF A MAGNETIC ATTITUDE CONTROL SYSTEM FOR SMALL SATELLITES

M.Ovchinnikov, V.Pen'kov, I.Kiryushkin, R.Nemuchinsky, A.Ilyin, N.Tretyakova
Keldysh Institute of Applied Mathematics of RAS, Russia

Abstract

Attitude control systems which provide small satellites with a required angular motion developing the control torque through interaction with the geomagnetic field are considered. They can be passive or active in regard with the purpose of a satellite. Relatively low accuracy of orientation achieved by such systems can be ether accepted due to the purpose of the satellite or can be compensated through preprocessing the payload data. Next, the magnetic attitude control systems developed for the latest years followed by results of fly testing are presented.

20 June 2003, Friday

Session 15
Celestial Mechanics
08:20-10:00

15-1. EVOLUTION OF FORMATION FLYING SATELLITE RELATIVE MOTION: ANALYSIS BASED ON THE THEONA SATELLITE THEORY
Alexei Golikov
KIAM, KIA Systems

Abstract
Not available

15-2. MEASUREMENTS OF GRAVITATION FIELDS IN THE SOLAR SYSTEM AS NECESSARY STEP TO THE MICRO-ARCSECOND ACCURACY OF ASTROMETRY
V.I. Denisov,
Institute of Applied and Theoretic Investigations of the Moscow State University, Russia
A.V. Bagrov
Institute of Astronomy of the Russian Academy of Sciences, Russia

Abstract
Now two similar astrometrical projects are prepared in Russia and in USA. Both are based on pupil interferometry that allows to provide space observations with accuracy up to 10-5-10-6 arcseconds. This accuracy is so high that some gravitational effects, that not long time ago were subjects for experimental investigations for testing of basic nature lows, can put limits to the real accuracy of astrometrical catalogues and inertial co-ordinate system.

This is why we need to understand well all the effects that can distort positions of celestial objects and to consider them at processing of observational data.

15-3. IMPROVED ANALYTICAL METHOD FOR CALCULATION OF "THIRD-BODIES" PERTURBATIONS IN SATELLITE MOTION
Sergey Kudryavtsev
Sternberg Astronomical Institute of Moscow State University, Russia

Abstract
Accurate expansion of the perturbation function due to attraction of the "third-bodies" (Sun, Moon and planets) to a Poisson series is done. The series is built

through an improved harmonic analysis of the ephemerides DE/LE-406 over 3000BC - 3000AD. Unlike the results of classical Fourier analysis, both the amplitudes and frequencies of the obtained series are high-degree polynomials of time. The new expansion is applied to analytical prediction of both high- and low-altitude Earth's satellites motion. The work is supported in part by a grant number 02-02-16887 from the Russian Foundation for Basic Research.

15-4. GEOMETRICAL INTERPRETATION OF THE ANALYTICAL SOLUTION OF THE SATELLITE VERSION OF THE RESTRICTED THREE-BODY PROBLEM: APPLICATION TO SELECTION OF THE LONG-LIVE AES ORBITS

Victoria I. Prokhorenko
Space Research Institute Russian Academy of Sciences, Russia

Abstract

We turn our attention to the problem of the long-live AES orbit selection. The geometrical method is developed for the parametric analysis of the satellite orbits long-term evolution under action of the external bodies gravitational perturbations.

As a conceptual basis we use the analytical solution of the double-averaged circular Hill's problem obtained by Lidov (1961). We use, as an example, the high-apogee orbits of the AES ROGNOZ - series launched in 1972 to 1995. To apply the above-mentioned analytical solution to the problem of the four bodies (Earth, AES, Moon, and Sun) we use the assumption of the co-planarity of the Moon orbit and ecliptic planes. We compare the analytical estimation with the results of the numerical integration of the complete system of the differential equations taking into account the lunisolar gravitation perturbations.

15-5. THE INFLUENCE OF SOLAR AND GEOPHYSICAL ACTIVITY TO THE CHANGE OF SATELLITE ORBITS

Valentine Prokudina, Nadezhda Kolodiazhnaya, Darya Petukhova, Darya Mikhaylova
Moscow City Palace for Children (Youth) Creativity, Russia

Abstract

It is known that during solar activity it is observed the disturbance of the Earth magnetosphere, leading to the break of normal work of satellite and to the changes of its orbits.

We estimated the change of density at high atmosphere during the period of largest solar and geomagnetic activity at July 2000, using the model of Jacchia with parameters F 10.7 and Ap -indicies.

In addition to geomagnetic indicies we analysed the Belt Index which increased on several orders during the period of high level of magnetospheric activity because of the precipitation of energetic particles to atmosphere.

We investigated the periods, when several satellites worked with considerable breaks (for example May, 1998). Besides we analyzed the solar and geophysical data during the sharp descent of the KA MIR.

Session 16
LOW THRUST TRAJECTORIES
10:20-12:00

16-1. PRECISE MODELLING AND CALIBRATION OF THE CLUSTER MAIN ENGINE AND 10 N THRUSTERS

Jesus Cegarra,
GMV at ESA/ESOC, Germany
Gottlob Gienger,
European Space Operations Centre, European Space Agency, Germany

Abstract

The Cluster mission is a set of four spin stabilized spacecrafts forming a tetrahedron. Since their launch in July and August 2000 three constellation changes have been prepared and commanded.

A precise modelling, covering models for the thermodynamical behaviour of the helium and propellant, combined with a calibration method based on covariance analysis, has given very good manoeuvre performance. A new method is presented to calibrate a set of two axial Delta-V manoeuvres and one attitude slew with up to four different thrusters simultaneously. Implementation, results and benefits for the Cluster constellation manoeuvres are described in this paper.

16-2. MAIN BELT ASTEROID MISSIONS WITH LOW THRUST AND GRAVITY ASSIST OF MARS

R.Z.Akhmetshin , T.M.Eneev
KIAM, Russia

Abstract

The spacecraft which is now worked out for the "Fobos-Ground" project, cannot deliver the payload to asteroid of the Main Belt, necessary for relic ground sample return. Mission becomes possible if

the assist of Mars will be used (about twenty variants of missions were found for asteroids of all the main types C,E,I,M,O,S,U), or

the power of solar arrays will be increased (twice increasing allow to realize straight flights to many asteroids).

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16-3. SC INSERTION INTO HIGH WORKING ORBITS USING LIGHT-CLASS LAUNCHER AND ELECTRIC PROPULSION

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Abstract

It is considered spacecraft insertion into target orbits using light-class launch vehicles and electric propulsion. Typical flight profile includes insertion into a parking orbit using launch vehicle, transfer into an elliptical intermediate orbit using high-thrust upper stage, and transfer into target orbit using electric propulsion. The optimization of low-thrust transfer and intermediate orbit parameters is carried out. Available launch vehicles, upper stages, and electric propulsion are considered. There are presented dependencies of delivered mass with respect to transfer duration, spacecraft electrical power, and electric propulsion specific impulse. Presented results could be used for feasibility study of low-cost space missions.

16-4. OPTIMAL TRAJECTORIES FOR SPACE FLIGHT TO NEAR-EARTH ASTEROID USING ELECTRIC JET PROPULSION SYSTEM

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Abstract

Optimal trajectories for a space flight to a near-Earth asteroid (NEA) are presented. The flight aim is an impact-kinetic effect of the spacecraft (SC) upon the NEA, a correction of the NEA orbit and its deflection from the Earth. This deflection is maximized under the optimization. The SC has a combination of a chemical jet propulsion system and an electric one. Numerical results are given for the asteroid Toutatis orbit.