SpaceOps Conference Best Topic Papers
Summary 2006 – 2014
SpaceOps Key-Words

As a service to the SpaceOps community of the international SpaceOps Organization (see also Wikipedia https://en.wikipedia.org/wiki/SpaceOps) the following Wiki-style compilation provides a summary of peer-reviewed **SpaceOps Conference inovative papers since 2006** (including SpaceOps Conferences peer selected "**Best Topic Papers**") by sorting space operations specific topics according to **"key-words".**

This enables the interested reader to find the most current and relevant papers on a particular topic and trace the development of that subject over the past years from SpaceOps Conference 2006 onwards. The papers reflect the current understanding and "state-of-the-art" but also indicate new developments and trends.

A retrieval of the appropriate papers from the official AIAA SpaceOps archive is facilitated with the indicated links (blue). However the link-systematic has been changed several times over the years, so they are not directly linked to the current archive anymore (some still might work).
However, following the procedure below they still can be retrieved:

1. Lock into the SpaceOps AIAA Archive https://arc.aiaa.org/series/6.spaceops
2. Select the desired year (2002 through 2018)
3. Enter the DOI/ISBN search number in the format 10.2514/6.year-number
   The 10.2514/6 number stays fixed
   The year-number information can be derived from the key-word text below.
4. If you run into problems please address me at joachimkehr@aol.com

The SpaceOps Wiki "key-words" directory is current and includes the best topic papers of the most recent **SpaceOps 2018** Conference. From the next SpaceOps Conference 2020 onwards another archive will be applicable since the archiving task has been transferred to IAF.
Whether the key-word feature will be maintained is unknown at the time of this article.

As mentioned above, the official AIAA/SpaceOps conference archive covering the SpaceOps Conferences starting with the year 2002 can also be accessed directly.by clicking the link https://arc.aiaa.org/series/6.spaceops. Using this method the title of the paper must be known or the author.

The electronic archiving of Conference papers was pioneered in 1996 in connection with the SpaceOps Conference 1996 in Munich with DLR's SpaceOps1996 Electronic Publishing System (EPS). Due to the rapid progress of the internet this original archiving got lost in the system. The SpaceOps 1996 papers are only available on CD – which was also the first time the papers were not distributed as printed proceedings by SpaceOps.
The 2000 and 2004 SpaceOps Conference papers were only temporarily archived and distributed on CD, they are not accessible any longer, some might be found by searching the internet.

The available SpaceOps **key-word** definitions, which were developed over the years can be "browsed" in alphabetical order as summarized below.
Unfortunately the SpaceOps Wiki **online** site was discontinued by the provider in 2018.

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SpaceOps_Wiki " Key-Words " TOC *(Status: Aug 2018)*

K
Keyhole deflection

L
Lunar Orbital Platform Gateway
Layered Architecture
Logistics
Laser & Optical Communications
Launch Vehicles and Systems

M
Management (space operations)
Middleware
Mission Extension & End of Life (EoL) operations
Mission Operations
Mission Operations Assurance (MOA)
Mission Planning
Mission Simulation
Mobile Devices and Social Tools (for Satellite Operations
Monitoring and Control Systems (MCS) Multi-mission Operations
Multi-Purpose Crew Vehicle (MPCV)
Mission Re-Engineering

N
Navigation
Near Earth Objects (NEO) & LEO
Networks & Space Mobile Network (SMN)

O
On board Autonomy
On orbit Constraints Test (OOCT)
On orbit Servicing (OOS)
Operations Reliability
Operations System Design
Operations Tools
Outreach Programs

P
Public Private Partnership

R
Radiation Belt (Science operations planning)
Requirements Tracing
Return on Experience (ROE)
Refurbishment of operations Systems

S
Safety and Reliability
Science Operations
Security (Communications)
Service Oriented Architecture
Simulators
SLS (Space Launch System Program)
Software Development
Space Elevator
Spacecraft Operations
SpaceOps Organization

SpaceOps-Wiki

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A

Advance Planning and Scheduling Initiative (APSI)

A research project funded by ESA-ESOC in Nov. 2006. It aims to create a software framework to improve cost-effectiveness and flexibility of planning support tool development and it strives to bridge the gap between advanced Artificial Intelligence (AI) planning and scheduling technology and the world of mission planning. The paper 2008-3268 examines the operational flexibilities in the Mars Express mission and how these allow such AI constraint resolution techniques to be applied to the early 'science availability' definition with the APSI Case Study 1 Tool.

Architecture (Ground segment)

The quality of a ground segment architecture is defined by its efficiency implementing users requirements. Various methods are used. The advantages and experiences of two implementation approaches are presented: Functional architecture (2008-3503), open service oriented architecture (2008-3504),

Arraying

Arraying is the technical method to enhance the receiving capability for deep space missions by coupling various antennas available at the ground reception site. Paper 2008-3564 gives an overview of past techniques used by the NASA Deep Space Network (DSN), its contributions to the Spitzer telescope mission an future planning.

The promise of array technology in support of space operations has long been appreciated, and receiving array technology is now an important operational asset. Notable examples include the NRAO (National Radio Astronomy Observatory) array of twenty seven 25m reflectors and the DSN (Deep Space Network) ad hoc arraying of various assets, particularly 34m antennas , to realize significant G/T increases providing needed bandwidth and range extensions. However, uplink (transmit) arraying has not kept pace due to the difficulty of ensuring „open loop" beam formation under the conditions of wide spacing. The 2010 paper (2010-2175) presens an approach for mitigating these difficulties, offering the potential for continual readiness operationally and extensibility to Ka band.

Authentication

Authentication in operations is applied for user and/or hardware authentication in order to enhance operations security (see also à Security) by prohibiting unauthorized access. The use of Smartcards for operational purposes in the Columbus Control Center and associated supporting centers was introduced instead of suing username/password identification. The implementation and user experience is described in 2008-3326.

Automation

The execution of a process free from human intervention as much as feasible. Automation of operations attempts to substitute as many operational tasks as possible by automated processes, mainly by software routines, which classically would be executed by operations personnel. The main fields of operations automation are: telemetry analysis, failure detection and automated reaction to failures (failure correction), command and sequence generation. Automation of operations is achieved by implementation of centralized telemetry (TM), telecommand (TC), planning and scheduling tools requiring none or very little operator interactions (AIAA paper 2006-5532). Introduction of automation into operational systems is particularly challenging and cost-intensive. In human spaceflight, Astronauts add to the complexities as a consequence of unpredictable reactions (AIAA paper 2006-5533). Introduction of increasing levels of ground station remote monitor and control with no impact on quality of service is being exercised (AIAA paper 2006-5508). Automation of Space Segment with robotics: end-effectors and tool exchange require much more complex operations preparation (AIAA paper 2006-5509). The beneficial aspect of

automation is that more autonomy on board allows lower operations staffing in case of nominal behavior (AIAA paper 2006-5506); in case of contingencies, deeper expertise may be required, depending also on the level of validation in the onboard automation performed during mission preparation. A rich, 3-D, visualization environment can contribute to a virtual operational presence in space and supports terrestrial, distributed operations (AIAA paper 2006-5709). Definition and issues of an automated service within a mission operations framework (AIAA paper 2006-5741) is being investigated. Automation proposals for scientific image data collection by comparing the (changing) status of the observation object is a means to improve the efficiency of data return (Round Table).

Flight Procedures Automation:
The paper AIAA 2010-2286 describes the Satellite Procedure Execution Language and Library (SPELL) as open specification developed by SES and GMV together with its powerful scripting capabilities to automate flight procedures.

B

Best Practices Activities

The Space Operations and Support Technical Committee (SOSTC) of AIAA has established a "Best Practices" working group dedicated to Space Operations.
The most recent publications about ground systems development, satellite operations, and mission operations assurance (MOA) are accesible at the SOSTC Best Practices page.

C

Category-A DSN Missions

The NASA Deep Space Network (DSN) also supports near Earth missions, called Category-A missions, contrary to deep space missions. The paper 2008-3258 describes a roadmap for projected augmentations and new capabilities needed to meet the challenges imposed by these missions during the next two decades.

CCSDS Cross support

Cross Support Transfer Services (CSTS) are standardized services to allow interoperability between different space agencies for mission cross support. A service user from one agency can use services that are provided from the ground station belonging to another agency. The CCSDS Space Link Extension (SLE) services for delivery of spacecraft telemetry and telecommand between ground stations and control centers are very successful examples for these kinds of services. The CCSDS CSTS Standardization Working Group is currently working on a CCSDS Cross Support Transfer Service Specification Framework. The paper AIAA 2010-2281 gives a brief overview of the work of the CCSDS CSTS Standardization Working Group and introduces the concepts of the CSTS Specification Framework.

Collision Avoidance

The German Space Operations Center (GSOC) is currently building up an operational proximity monitoring and mitigation system. Proximity events are detected based on the “Two-line Elements” (TLEs) and precise orbit information from locally operated missions. Despite evident deficiencies in the quality and timeliness of the available orbit information, TLEs are currently the only source of orbit information for the numerous space objects. The TLE uncertainty needs to be therefore carefully assessed for the collision risk estimation. Even after a realistic error analysis, the orbit information of a possible jeopardizing object has to be refined for a proper planning and implementation of collision avoidance maneuvers. For this purpose, the use of radar tracking is currently planned, for which an accuracy assessment is to be considered. In the paper AIAA 2010-2298, following the presentation of the collision avoidance procedure at GSOC, the orbit accuracy and the orbit refinement by a radar tracking is discussed followed by its application to the collision avoidance system. The paper concludes with the presentation of GSOC’s collision risk monitoring system and how close approaches are handled.

Commercial Orbital Transportation Services (COTS)

Space operations have evolved slowly but steadily over the last half century, driven primarily by computing and software developments implemented in both ground and space segments. The next decade could, however, see a paradigm shift in the scope and nature of space operations as a consequence of NewSpace activities, which have the potential to deliver major improvements in space access – in terms of cost, availability and reliability – and thereby increase the number and diversity of missions, especially those involving humans.

While similar claims in the past have proved to be merely false dawns (Cf. the original rationale for Shuttle) there is good reason to believe that on-going developments are far more likely to lead to such a paradigm shift. The paper 2010-1972 sets out the justifications for such optimism and discusses their implications with respect to both the scope and nature of space operations during the coming decade. See also SpaceOps "Communicator" article on Commercial Spöaceflight

Commercial Spaceports

Airports have begun incorporating Spaceport infrastructure and cooperative operations. We are witnessing the evolution of the Aerospaceport. For many years Spaceports were exclusively developed by the Federal Government. They then evolved to also include a State - Federal based model. The paper AIAA 2010-2149 discusses the technical, cost, schedule and political requirements of the launch vehicle programs which influenced the evolution of the Aerospaceport development models. It then compares and contrasts the differing requirements of Federal, State and private spaceports which influence the ultimate decision of where to conduct a launch.

Commercial Crew Developmet (CCDev)

In the quest to increase accessibility to space under CCDev contracts, SpaceX has strived to optimize the use of automation and process/communications flow to allow the human operator a better focus on decision making and thus ensure repeatable, efficient and reliable operations.

While remaining cognizant of the unique and challenging environment of spaceflight and respecting over 50 years of experience of space operations, SpaceX is applying the best practices from our industry as well as other operationally-focused industries in a solution tailored for the 21st century. SpaceX has developed spacecraft launch and on-orbit control systems using graphically-driven displays and state-of-the-art architectures that result in a positive redistribution of workloads. In addition, the use of off-the-shelf tools and standard computer platforms have allowed mission operators to concentrate on the spacecraft rather than the ground system. Simulation and flight experience have already shown improvements in allowing the operator to look further out in the mission and manage operations as presented in AIAA 2010-1937.

Commercial Operations

The paper AIAA 2010-1950 reviews how commercial operations have influenced the RADARSAT-2 operations concept from a mission management perspective, and describes the mission management approach.

Communications Technology

Technology for establishing communications between a spacecraft and the appropriate ground segment (ground based facilities).
It comprises all means of communications and associated technical support systems used between a spacecraft (manned or unmanned) and the ground personnel (flight and payload operators). Space communications (Space-to-Ground, Ground-to-Space and Space-to-Space) always demand higher transmission capabilities (data rates and protocols) for up- and downlink data transfer. Interesting and promising validation results of interplanetary Ka-band link (high rate) communications usage were presented at SpaceOps 2006 AIAA paper 2006-5787. The ESA Ground segment Management is looking into Ka-band expansion as well (Plenary Session, "SpaceOps 2006"). For interplanetary (e.g. Lunar/Mars) missions, it is proposed to use IP rather than point-to-point protocols (Round Table). Operations of satellites in Low-Earth Orbit (LEO) have been based on exploiting the maximum time of visibility of satellites over their ground stations. In a 2010 paper (2010-1942), it is shown that a key parameter for communication between a satellite and a ground station is not the time of visibility but the amount of telemetry data which can be transmitted from the satellite to the ground station in the downlink. New MARS an MOON communication technologies were discussed in the 2016 Conference:
AIAA 2016-2355: Enabling International Data Relay at Mars
AIAA 2016-2419: The Lunar Space Communications Architecture (from The KARI-NASA Joint Study).

Constellation

Constellation is the name of the NASA program to implement the “Vision for Space Exploration” (VSE) as installed by President George W. Bush consisting of the shuttle derived two stage launcher Ares I (2008-3562) to service together with the crew transport vehicle “Orion Orbiter” the ISS. The Ares V launch vehicle will transport “Orion” together with the moon lander “Altair” into earth orbit to be docked

there and maneuvered into a moon trajectory. “Altair” will land on the moon while “Orion” is orbiting the moon waiting for “Altair’s” return to fly the crew safely back to earth. The same concept might be applied for exploring Mars.Ground operations aspects for the Ares I and Ares V launch vehicles are described in 2008-3563
Telecom satellite fleet hassle free operations (AIAA2016-2418) discusses an end-to-end automation system. Another automation approach is provided in AIAA 2016-2387: Flying Large Constellations Using Automation and Big Data.

Crew Autonomy

The degree of on-board control. Theoretically, total crew autonomy would be a self-contained, independent flight system without any interaction with ground operators. A certain degree of crew autonomy is mandatory with independent and automated on-board planning systems AIAA paper 2006-5526, because of the creasing delay-times for long distance human spaceflight.

Cost effective operations

EUMETSAT, the EUropean organisation for the exploitation of METeorological SATellites exploits since 1977 the METEOSAT series and, since 2004 the Meteosat Second Generation (MSG) satellites which deliver meteorological observations from geostationary orbit with stringent data timeliness and operational availability requirements. The Meteosat Third Generation (MTG) programme will take over MSG, starting in 2017 for the next 20 years, as an answer to the expanding needs for satellite based meteorological data due to the continuous development of Numerical Weather Prediction capabilities. The paper selected as one of the "best papers" in 2010 (AIAA 2010-1979) is introducing the main aspects of the cost effective approach that has driven the system specification activity and hence led to operations characteristics of the MTG system. A presentation of the major technical and programmatic drivers for the anticipated MTG operations is proposed, including for instance, the high degree of ground and space operations automation, the increased satellite autonomy, satellites co-location, the optimisation of TM/TC antenna usage, the remote accessibility to the system monitoring capabilities from outside the control rooms, the introduction or re-use of multi-programme ground segment facilities. Evolutions since the MSG operations concept elaborated before the launch are also provided where appropriate to highlight the evolution from the current programme to the next one.

Cubesat

"Cubesat" was added a new "key word" for the SpaceOps 2016 Conference because of the growing actuality of mini-satellites, called "cubesats":
AIAA 2016-2493: Cubesat Development for CANYVAL-X Mission
AIAA 2016-2491: MarCO: Interplanetary Mission Development on a CubeSat Scale
AIAA 2018-2633 A novel approach to expand the use of cubesats for very ambitious applications with significant relevance for the future.
In paper AIAA 2018 2599 the LUMINO mission concept is described and focuses on the performance of a novel navigation concept.

D

Debris

Space Debris mitigation is of utmost importance for GEO satellites. An overview of the main activities being carried out at EUMETSAT in the frame of space debris mitigation recommendations, and in particular in the areas of collision risk mitigation and End-Of-Life practices, is presented in the paper AIAA 2010-1959..

One of the selected SpaceOps2012 Conference "best papers" (AIAA-2012-1295493) describes a commercial collaboration for collision avoidance by establishing a Space Data Center (SDC). The paper describes the SDC architectureand operations, exposing unique capabilities and lessons learned since its inception in 2009.

Another "best topic paper" of the SpaceOps2012 Conference considers space debris mitigation requirements for LEO missions (AIAA-2012-1257086). The method developed by ESA alows the analysis of global compliance with the request to limit the orbital lifetime of a spacecraft to a period no longer than 25 years after the end of the mission by using publicly availble orbit data.

The SpaceOps2014 Conference addressed the growing concern about space debris which could become a runaway environment ("Kessler Syndrome"). To prevent this secnario Los Alamos National Laboratories established the goal to develop an integrated system of amospheric drag moedling, orbit propagation and conjunction analysis with detailed uncertainty qualification to address the space debris and collision avoidance problem. Components and capabilities of this "IMPACT" framework is presented in paper AIAA 2014-1771.

Deep Space Operations

The SpaceOps0214 Conference addressed various deep space operations aspects. Innovative "best topic" papers were:
AIAA 2014-1716: Presenting the incorporation of human health and human factors insights into possible vehicle designs for trans-lunar space.
AIAA 2014-1625: This paper presents the development of a two stage Mars Ascent Vehicle (MAV) using in-situ propellant production. The examined schemes utilize CO2 and water as starting blockes to produce LOX and a propane blend. The infrastructure to fuel and launch the MAV is also explored.
AIAA 2014-1634: This paper is exploring the possibilities to use JPL's Advanced Multimission Operation System (AMMOS) Ground Data System (GDS) for the support of future deep space CubeSat missions.

Delay and Disruption Tolerant Network (DTN)

A communications network accepting delays in the transmission and reception processes.
Delay tolerant networks are needed to cope with the traveling times of electrical signals through long distances in space, i.e. reaction times to occurrences on board a spacecraft could be in the order of hours. Because of the increasing delay-times for long distance human spaceflight the methods of establishing more delay tolerant networks is being considered (AIAA paper 2006-5526) . Disruption tolerant networks need to cope with breaks in the communication chains, modeled after the Internet. DTN automates the store and forward process within an available network of communication satellites and ground stations to transfer data from spacecraft to the intended receiver (preliminary results: see test in Nov. 2008, Richard Doyle, NASA Jet Propulsion Laboratory). For application testing see also the recent Communicator article Internet in Space Testing.

In 2010 a paper (2010-2206) was presented dealing with four major developmental areas (system architecture, data definition/usage, application architecture, and tool implementation) critical to the maturation of this ability. Within each developmental area implementation recommendations are presented and current threads of research. Ultimately, it was concluded that closed-loop network management of DTNs is not viable and architectures that promote status telemetry over control loops, autonomous decision making over static configuration, and locality over global administration must be engineered for these networks.
Paper AIAA-2018 2429 discusses the existing Relay Services architecture at Mars and considers how several technologies may be applied to the next generation of relay services at Mars.

The SpaceOps2012 Conference "best topic paper": "The Delay-Tolerant Networking Engineering Network", AIAA-2012-1290363) describes the DTN Engineering Network (DEN) testbed comprised of physical and virtual machines and flight-like hardware located at different NASA-centers and supporting universities. Its design, construction test excecution, and anticipated evlution is outlined.

DSN Schedule Automation

The DSN Scheduling Engine (DSE) is described in paper AIAA 2010-2265, It has been developed to increase the level of automated scheduling support available to users of NASA's Deep Space Network (DSN). Another "best topic paper" of the SpaceOps2012 conference deals with the automation of the DSN scheduling process wrt mid- und longrange schedule describing the Seervice Scheduling Software (SSS, or S3):
AIAA-2012-1296235.

Emergency Scheduling

The SpaceOps2012 "best topic paper" AIAA-2012-1261910: "Emergency Scheduling of Multiple Imaging Satellites with Dynamic Merging" (National University of Defense Technology, Changsha, China) a novel dynamic emergency scheduling model of multiple imaging satellites is established: A novel task dynamic merging strategy, developing an alternative task set establishment (ATSE) algorithm used for dynamic merging is proposed. In addition a novel dynamic emergency scheduling algorithm called DM-DES is presented, which considers the dynamic merging.

Another "best topic paper", the "FAST: A new Mars Express Operations concept, quickly!" (AIAA-2012-1257123) describes a new operations concept which had to be introduced because the Mars Express on-board Solid State Mass Memory (SSMM) sufferd from anomalies, the File-based Activities with Short Timeline (FAST) was devised to restart science operations as soon as possible.

F

Failover

The act of switching to a different, redundant system upon the failure or abnormal behavior and/or termination of the currently-active system.

Formation Control, Swarms

Formation, swarms are constellations of identical or similar spacecrafts with identical/similar mission objectives being deployed to make it possible to achieve and/or enhance the mission goals in an cost efficient manner. The control of multiple spacecraft (swarms) having the same mission goals but are spatially separated is called formation control. Formation control requires sophisticated control systems to avoid duplication of efforts and facilitation of efficient operations. With increasing use of smaller but multiple (identical) application satellites the intelligent co-ordination and control of the formation constituents becomes more difficult than operations of a single spacecraft. Use of magnetic fields to maintain the formation co-ordination is proposed (2006-5886). Large numbers of multiple agents within a swarm must be multiple failure tolerant and the agents must co-operate with each other for the achievements of their “high level” goals (2006-5555).

In 2010 a paper (AIAA 2010-1989) was presented to discuss the combined mission planning aspects of TerraSaAR-X and TenDEM-X. The combined TerraSAR-X / TanDEM-X mission planning system will handle the two satellites as well as two completely different missions with their different mission goals. As a consequence, the new combined TerraSAR-X / TanDEM-X mission planning system not only has to support two satellites with their mutual constraints, but also will handle two different missions at the same time: the long-term mapping approach of the TanDEM-X mission and the short-term on-demand approach of the TerraSAR-X mission. There are two critical issues regarding the operational safety of the formation flight: the close distance of the two satellites implies a significant collision risk in case of anomalies. Next, illuminating the other satellite with radar pulses can cause severe damage to the illuminated satellitel

G

Ground Operations (Methods and Tools)

All activities in or between ground based facilities for monitoring and controlling spacecraft during their mission as well securing the mission return. It covers the preparation, qualification and operations of a mission-dedicated ground segment and appropriate infrastructure including Antennas, Control Centers and Communication means and Interfaces. Ground operations in this context covers the design, implementation and qualification of a particular ground segment, the provision of ground segment operations tools, provision of simulation means, ground segment operation, configuration management and maintenance of the ground segment. The main challenge is the implementation and operations of high-quality, cost-efficient and secure space-to-ground, space-to-space and ground-to-ground communications respecting a multitude of different standards and protocols (see also papers in the categories Standards, Ground Systems, Communications and Tracking).

In the SpaceOps2014 Conference the DLR/GSOC "best topic" paper AIAA 2014-1807 presented a new approach to ground station scheduling as an interoperability service respecting the associated security aspects

One of the 2016 Conference best topic papers was about signal acquisition after large apogee raising maneuvers:

AIAA 2016-2428: LISA Pathfinder: New Methods for Acquisition of Signal after large Apogee Raising Maneuvers

A new "plug & play" approach for Ground Stations was presented in:

AIAA 2016 -2583: Doing the same - But differently. Plug & Play Solutions for Ground System Operations

Ground Station Development

In the 2016 Conference managment aspects for the development of new Ground stations was discussed:
AIAA 2016-2371: Managing Expectations for Ground Station Development at Awarua, New Zealand.
AIAA 2018-2403: This “best paper” presents the transfer, integration and expansion of existing NOAA-NESDIS ground facilities (stovepiped design) into a more efficient and modern multi-service oriented architecture making leveraging the Cloud for archiving and shared product generation..

Ground System Reliability

Success of the Constellation Program’s lunar architecture requires successfully launching two vehicles, Ares I/Orion and Ares V/Altair, within a very limited time period. The reliability and maintainability of flight vehicles and ground systems must deliver a high probability of successfully launching the second vehicle in order to avoid wasting the on-orbit asset launched by the first vehicle. The Ground Operations Project determined which ground subsystems had the potential to affect the probability of the second launch and allocated quantitative availability requirements to these subsystems. The Ground Operations Project also developed a methodology to estimate subsystem reliability, availability, and maintainability to ensure that ground subsystems complied with allocated launch availability and maintainability requirements. The verification analysis developed quantitative estimates of subsystem availability based on design documentation, testing results, and other information.

This case study (AIAA 2010-2180) will discuss the subsystem requirements allocation process, describe the ground systems methodology for completing quantitative reliability, availability, and maintainability analysis, and present findings and observation based on analysis.

GPS for GEO Satellites

The interesting question under what preconditions the Global Positioning System (GPS) could be used for satellites in geosationary orbit (GEO) was discussed in an interview with European flight dynamics experts in the "Journal of Space Operations & Communicator "

Ground Network Renewal & Upgrading

The "best topic paper" "CNES Ground Network Renewal" (https://doi.org/10.2514/5.9781624102080.0259.0284) addresses the challenges of increasing the network capacity and reduce operations cost. The details are tackled in a project called "CORMORAN" - the paper describes all the components and rationale.
Paper AIAA 2018-2628 aims at showing how CNES – operating more than 15 missions - has chosen to continue to improve its global efficiency for mission operations systems development and for spacecraft operations. In order to find a better development and operations cost optimization, as well as an optimization of the organization of its space operations
Paper AIAA 2018-2403 presents the transfer, integration and expansion of existing NOAA-NESDIS ground facilities (stovepiped designed) into a more efficient and modern multi-service oriented architecture.

H

Handover (Hand off)
The act of relinquishing a system and/or its control authority to a different, redundant system.

I

Impact Prediction

The paper AIAA 2010-2006 and associated ePoster provides a visualization of the issues involved in predicting the visibility of a lunar impact event from an Earth-orbiting spacecraft. The example chosen was the visibility of the Lunar Crater Observation and Sensing Satellite (LCROSS) impact on the Moon from the Hubble Space Telescope (HST).

Inter-Agency Space Debris Coordination Committee (IDAG)

The Inter-Agency Space Debris Coordination Committee is a committee dealing with all aspects of space debris (see also "Communicator" article "Exploded in Space"). See also -> "Debris"

International Collaboration

The collaboration of international space agencies or other appropriate institutions for the purpose of efficiently achieving common goals by sharing their know-how and resources. International collaboration in space projects grew from very limited collaboration during the beginning of spaceflight ("space-race") to international collaborations e.g., for the ISS (main partners: USA, Europe, Canada, Russia, Japan) and is expected to grow for the "Vision of Space Exploration" (VSE). One important aspect of International Collaboration would be the free exchange of know-how and hardware between the participants. International Traffic and Arms Regulations (ITAR) must be addressed to resolve issues of International collaboration with the USA (from the discussion after the presentation of the paper: "Critical Management Needs in International Space Collaboration" AIAA paper 2006-5784 .

Internet for Space

Describes the efforts to expand earth-based Internet technology into space. With growing standardization, it is conceivable that transferring Internet technology into space would enable more efficient and economic communications for human spaceflight. Internet for space to be used for long-duration human spaceflight is being suggested AIAA paper 2006-5526

Interoperability

The capability to use other than the original planned communications resources to conduct a specific mission.
Scope and dynamics of spaceflight operations are changing - more interrelated platforms require more interoperability. Universal numbering schemes, XML/UDL schemas, messaging transport is requested. One proposal is to establish a Registry of Registries of "closed" systems with the appropriate information AIAA paper 2006-5777
The MOIMS SM&C Working Group within CCSDS is developing the Mission Operations Services Concept to address this problem space. The set of proposed standards presents a SOA to increase the level of interoperability among space agencies38. For the current status see paper AIAA 2010-2338.

K

Keyhole deflection

Keyholes are small regions in space near Earth through which a passing Near Earth Object (NEO) orbit may be perturbed due to gravitational effects, possibly placing it onto a path that would impact earth. An asteriod, which is called 2011 AG5, is about 140 meters wide. It may come close enough to Earth in 2040 that some researchers are calling for a discussion about how to deflect it. 2011 AG5 may zip through such a keyhole on its close approach to Earth in February 2023 (Space News, March 5, 2012).

L

Launch Vehicles

The SpaceOps2014 Conference paper AIAA-2014-1897 presents a subsonic air-launched RLV after a very thorough ananlysis of the history of launch vehicle developments. It's conclusion is that a RLV having a modest 5t -to near earth-orbit performance could be capable of supporting almost all current and future launch demand.
AIAA 2018-2489 A “must-read” paper for all potential users of the Ariane-6 launch system

Layered Architecture

Combines Commercial-Off-The-Shelf (COTS) products AIAA paper 2006-5532 and mission-specific software. Common due to its cost effectiveness AIAA paper 2006-5678 .

Logistics

Automated and other tools for on-board tracking of equipment to make efficient use of limited stowage room and to facilitate easy retrieval of stowed equipment. Radio Frequency object identification (super-market approach) for solving ISS on-board logistics problems is one option for solving the increasingly complex on-board logistics problems for long-duration human spaceflight AIAA paper 2006-5733.

Laser Communications (Optical Communications)

The "best topic paper" AIAA-2012-1261897 describes the NASA Laser Communications Relay Demonstration (LCRD) project, the architecture of which will allow to serve as a testbed for the development of additional symbol coding, link and network layer protocols, etc.
Another "best topic paper" from the SpaceOps2012 Conference ("EDRS Precursor Systems at GSOC", AIAA-2012-1275210) illustrates the design of the Technology Demonstration Payload No.1 (TDP-1) for the demonstration of a data relay service, using an optical High Data Rate Inter-Satellite Link (ISL) between a Laser Communication Terminal (LCT) located on a LEO satellite and a second LCT placed on a GEO satllite. The service to be demonstrated is the optical data link between the LCT's of the satellites and a link from a satellite to a grond station.
Paper AIAA 2018-2654 describes the impact of the routine OCP (Optical Communications Payload) operations on important operational areas and will also summarize the benefits to each mission of optical communications, showing how the use of optical communications, together with X-band ground station downlinks, has been used to maximize the data output of the missions.

Lunar Orbital Platform Gateway (“Gateway”)

Paper AIAA-2018 2464 discusses an overall operations concept for the Gateway, how the different ground operation centers could interact as well as operations occurring at the Gateway itself, both autonomous and crew involved. NASA has outlined a phased approach to expand human presence deeper into the solar system starting with the Moon. Phase 1 of this plan begins in the 2020s

M

Management (space operations)

Management for space operations means the co-ordination and execution control for space missions.covers all management tasks for preparing and operating a particular mission. The main talent expected is an expert level of technical understanding of spacecraft and ground operations requirements resulting in the planning and execution of all defined activities within a given schedule and within the available budget. Managers should also have a good understanding of the organizational influences on Spacecraft and Ground Operations in order to minimize risks of mishaps and accidents and the behavioral aspects of human error in the conduct of the mission operations. For cooperative International missions, managerial skills in dealing with International Partners and Agencies and intimate knowledge of the "culture" and policy of their own Organization/Agency is considered to be mandatory.

(see papers in the category Mission Management).

One of the SpaceOps2012 Conference selected "best papers" (AIAA-2012-1293551) describes a mission operations preparation environment as a "system of systems" to provide a complete overall picture for the integration of the spacecraft systems with the operations environment (MOIS&MORE).

Middleware

Software or hardware components introduced to interconnect different, in-homogenous software programs or layers. See AIAA papers 2006-5743, 2006-5573 , 2006-5550 , 2006-5704 .

Message Oriented Middleware (MOM):

There will always be a new “latest and greatest” architecture for satellite ground systems. This paper discusses the use of a proven message-oriented middleware (MOM) architecture using publish/subscribe functions and the strengths it brings to these mission critical systems. An even newer approach gaining popularity is Service Oriented Architectures (SOAs). A MOM vs. SOA discussion can highlight capabilities supported or enabled by the underlying architecture and can identify benefits of MOMs and SOAs when applied to differing sets of mission requirements or evaluation criteria, see AIAA 2010-1903. .

Mission Extension & End of Life (EoL) Operations

One of the 2012 "best papers"(AIAA-2012-1295834) describes the essentials of the NASA Senior review process to approve the extension of successful missions on prominent examples like Voyager, Magellan, Ulysses, Galileo, Mars Esploration Rovers, Cassini etc.
During the 2016 conference the Venus Express end-of-life operations was discussed (AIAA 2016-2361): Venus Express End of Life Operations - or the art of saying good-bye (AIAA 2016-2361). Another aspect of using EoL activities was suggested in paper AIAA 2016-2408:
TAKE5 Experiment Jazzes up SPOT5’s End of Operational Life, Using it to Simulate the new Sentinel-2 Mission.

Mission Operations

A SpaceOps2014 conference paper introduced a new idea for flight and ground operations integration by addressing the commanding and sequencing system for deep space mission operations with Virtual Machine Language (VML) sequencing. VML state machines replace sequences with reactive logic constructs capable of autonomous decision making within their prescribed domain (AIAA 2014-1830).
A file based operations architecture for EUCLIC (to be launched in 2020), based on CCSDS File Delivery Protocol (CFDP) is described in SpaceOps2014 paper AIAA 2014-1750.
In paper AIAA-2018 2450 the ethological method for HF assessment within the operator/system interactions during satellites control-command operations is studied and presented.
In paper AIAA 2018 2533 a large number of time series of telemetry data are analyzed in order to detect anomalies. In this paper a review of such analysis focusing on methods that rely on features extraction is provided.

Mission Operations Assurance (MOA)

Mission Operations Assurance (MOA) principles are fully described by a AIAA-SOSTC subgroup under "Best Practices" (see also "Best Practices").

Mission Planning

Mission planning is the activity to plan the execution of a mission according to its defined mission goals. Mission planning activities include planning of the space segment, the ground segment and all astronaut activities. Mission planning tools constitute an essential part of à Operations Tools.With increasing complexity of the missions the planning tools use artificial intelligence to automize the planning effort. A planning tool framework based on AI is described in 2008-3268. A new Multi-satellite mission planning system is presented in 2008-3488. A planning system reacting on very short notice times is introduced in 2008-3487.
A prototype for an on-board, goal-oriented replanning system was developed. With the lessons learned from this prototype, INPE (Brazilian National Institute for Space Research) implemented an on-board service that provides states inference, which can be used as an autonomy kernel by autonomous applications (ISIS), see AIAA 2010-2364
The "Timeline as Unifying Concept for Spacecraft Operations" is introduced and defined as a general, standardized tool for decreasing development cost in one of the "best papers" selscted at 2012 SpaceOps Conference (AIAA-2012-1274906).
Also a SpaceOps 2012 Conference "best topic paper", the "Innovative Rover Operations Concepts - Autonomous Planner (IRONCAP) - Supporting Rover Operations Planning on Ground" (AIAA-2012-1294460) defines the concepts, techniques ande interaction neede to plan an schedule the activities of an interplanetars rover resulting in the development of a prototypes system. The "Planning and Execution of the Tele-Robotic maintenance Operations on the ISS"
AIAA-2012-1272635 describes the planning and execution of Dextres's first tele-robotic operations. Ground-controlled operations are shown to be an effective method to maximize external maintenance capability.
The ever present topic of mission planning was addressed in the SpaeOps2014 Conference with two new, outstanding papers:
AIAA 2014-1889: ESA's report on the building a mission planning framework for the Rosetta and Bepi Colombo missions.
AIAA 2014-1785: GSOC's paper describes their future incremental planning system providing the advantage of immediate timeline updates (incremental updating) in contrast to conventional planning systems being only updated with the latest customer requests at fixed time intervals.
Noteworthy ideas for mission planning/scheduling were put forth also during the SpaceOps Conference2016:
AIAA 2016-2596 Rosetta / BepiColombo Mission Planning System: from mission to infrastructure
AIAA 2016-2623Accommodating Navigation Uncertainties in the Pluto Encounter Sequence Design
AIAA 2016-2487 PHILAE Lander: a scheduling challenge
AIAA-2018-2525 Pioneering mission planning techniques for many manned and unmanned missions the TerraSARanDEM-X based DLR system was improved again with the introduction of hard to predict variables. The paper definitively will inspire further improvements for further missions.
AIAA-2018-2498: Interesting approach since nature is always a good teacher – it remains to be traded off whether the introduction of a new strategy justifies the effort for a specific mission
AIAA-2018-2552: The combination of inherited software systems into a single multi mission tool is a powerful effort to reduce cost, however side effects like project duration(s), maintenance, compatibility and interface control have to be taken into account.
Paper AIAA 2018-2494 presents the terrain-based analyses performed for a Lunar Exploration Rover (LER) the first TeamIndus lunar mission, designated Z-01.

Mobile Devices and Social Tools (for Satellite Operations)
The SpaceOps2012 Conference paper "Location Independent Mission Operations - A Systems Engineering Approach to Mobile Device Data Disseminatoin" (AIAA-2012-1291658) recognizes the high mobility of computationally capable tablets, such as iOS and Android devices and their applicability for mission operations. The paper outlines the necessary system analysis and design activites for a risk free introduction of those capabilites. Another SpaceOps2012 "best topic paper" "Simplify ISS Flight Control Communications and Log keeping via Social Tools and Techniques" (AIAA-2012-1276528) explores three evolutionary ground system concepts under development at the three NASA ISS control centers by introducing "social tools and techniques" . These concepts aim to reduce ISS control center voice traffic and console logging yet increase the efficiency and effectiveness of both.

Monitoring and Control Systems (MCS)

Virtualization is a technology that allows emulating a complete computer platform. The potential use ranges from consolidating hardware to running several different operating systems in parallel on one computer to preserving the operability of heritage software. GSOC has been investigating the possibilities of virtualization for some time. Aside from the usual approach of virtualizing the central servers out of administrational, consolidational reasons, the possibilities and advantages of control room client virtualization was explored. While moving mainstream in other businesses, the space community is cautious to apply this technique to the mission critical monitoring and control systems. The paper AIAA 2010-2340 (one of the 2010 selected best papers) illustrates three virtualization steps that are underway at GSOC and presents the experiences gained. At the SpaceOps 2012 conference a University-developed "Comprehensive Open-architecture Space Mission Operations System" (COSMOS), AIAA-2012-1296468, was introduced and selected as one of the "best papers". The basic philosophy of this architecture is that its elements (tools and programs) will be easy to port to new location and to be modified for operating with new spacecraft.

Multi-mission Operations

Operations of multiple and usually similar spacecraft with a minimum of operations staff. The concept capitalizes on the same set of multi-skilled operators using common software/hardware/ground architecture components for more than one mission. As a result, multi-mission operations manpower savings reduces operations cost for a specific mission (AIAA paper 2006-5838). Multi-mission approaches are considered sufficiently mature for standardization (Round Table).
One of the selected SpaceOps2012 "best papers" (AIAA-2012-1295418) proposes a more efficient way to multi-mission operations by creating pools of specialists e.g., for attitude and orbit control, power/thermal etc., the pools forming the Operations Enginering Group being able to efficiently support multiple projects.
AIAA- 2018-2697 As demonstrated in previous missions the maximum use of a long lasting mission with aging hardware (and software) problems the effectiveness of an mission extension and its justification basically depends on the skills of the mission operations team. Although the experience discussed in this paper is very mission specific it might inspire other mission operations teams around the world.
AIAA 2018-2664 Specialized mission operations paper on ingenious recovery methods for a failed attitude control system

Multi-Purpose Crew Vehicle (MPCV)

NASA interplanetary capsule for crew transport to the ISS and deep space after Shuttle system retirement in 2011.

Mission Re-Engineering

One of the SpaceOps2012 "best papers" (AIAA- 2012-1285801) suggests a re-engineering method to eliminate unforeseen design inefficiencies during operations using the Spitzer mission as an example. It is recommended to include a formal re-engineering evaluation period in the life-cycle phases of a mission.

Mission Simulation (Analogue Missions)

This new topic was introduced during the SpaceOps2016 conference, it deals with the subject of "analog missions". AIAA-2016-2384:Operational Feasibility of Human-Robotic Analog Planetary Missions: An analysis from AMDEE AIAA 2016-2353 ANALOGUES FOR PREPARING ROBOTIC AND HUMAN EXPLORATION ON THE MOON. Paper AIAA 2018 2469 demonstrates that mission level simulations have had a profound impact on the Europa Clipper project, the spacecraft, and the mission design

N

Navigation

At the SpaceOps2014 Conference NASA presented its Deep Space Atomic Clock (DSAC) mission with the goal to develop a small, highly stable mercury ion atomic clock with an Allan deviation of most 1e-14 at one day.
Potential deep space applications of DSAC are presented in AIAA 2014-1856. AIAA-2016-2468 At the 2016 conference flight dynamics operational experiences on GALILEO were presented:
CNES and ESOC Flight Dynamics Operational Experience on GALILEO First Nominal FOC Launch and Fine Positioning Activities
AIAA 2016-2427 discussed the orbit **transfers** for DAW's CERES operatiosn: Orbit Transfers for Dawn's Ceres Operations: Navigation and Mission Design Experience at a Dwarf Planet.
AIAA-2018-2434 describes the design, implementation, re-implementation and operations of the Cassini Huygens navigation system.
AIAA-2018-2537 This paper discusses the latest experience with aero-braking techniques – an important talent to be mastered for re-entry and descent activities on Earth and all planetary and interplanetary explorations
AIAA-2018-2646 The use of Gravity assist techniques is another precondition for exploring interplanetary space and going to places which could not be reached using conventional propulsion techniques. The successful application for the Cassini mission demonstrates JPL's dominance in this field.
AIAA 2018-2716 Specialized paper on micro-propulsion systems (MPS). It is concluded that although the MPS is a new propulsion technology with highly challenged performances, its in-orbit behaviour is excellent in meeting Gaia's and LPF's unparalleled requirements in terms of attitude and rate stability

Near Earth Objects (NEO & LEO)

The 2009 Augustine Committee review of U.S. human spaceflight plans cited Near-Earth Objects (NEOs) as promising, practical astronaut destinations. These astronaut expeditions beyond the Moon offer dramatic next steps toward economic opportunity in Earth-Moon space, and the eventual exploration of Mars and beyond. The current status is discussed in paper AIAA 2010-2350
LEO object tracking was presented at the 2016 Conference:
AIAA 2016-2520 Performance Analysis of LEO object Tracking Using Mono-static And Bi-static Radar

Networks incl. Space Mobile Networks (SMN)

NASA has identified a standardized, heterogeneous wireless mesh network as a key technology for future human and robotic space exploration to be used for space proximity and surface applications. Test results were presented in SpaceOps2014 paper AIAA 2014-1600.

The SpaceOps2014 paper AIAA 2014-1822 describes the architecture and the operations concept of an EDRS (European Data Relay Satellite) Feeder Link from Antarctic Latitudes (EFAL) to improve the near real time delivery of high rate data from satellites in polar orbit.

The AIAA 2014-1829 paper describes security standards for space-terrestrial internetworks. It presents the JHU/APL work to develop security standards for end-to-end overlay internetworks utilizing Delay-Tolerant Netwroking Bundel Protocol (BP).
Paper AIAA 2018-2514 describes how the CNES concepts of operations, with the Return Link Service Provider (RLSP)
Paper AIAA 2018-2672 describes the approach of the Dynamic Network Analysis (DNA) interactive visualization tool and the importance of having a graph-based visualization capability in space operations to comprehend relationships at stake in different kind of problems with the help of a demonstrator.
Paper AIAA-2018 2423 details how SMN concepts such as user-initiated services, which will enable users to request access to high-performance link resources in response to real-time science or operational events, would be applied in and beyond the near-Earth regime.
Paper AIAA 2018-2554 describes the hybrid antenna design, the technical challenges being addressed, and plan for using this concept, together with ongoing work on optical flight terminals
Paper AIAA-2018-2528 focuses on the overall deep space future mission needs: how they were derived, what the trends and implications are, how well different architectural approaches to Deep Space Network capacity appear to satisfy the projected aggregate mission set demand, and what recommendations emerge from these considerations.

O

On board Autonomy

The paper AIAA 2010-1968 will discuss the AEOLUS on-board autonomy in particular related to the instrument routine operations and failure recovery, present an outline of the AEOLUS Mission Planning system and provide an overview of the automation implemented in the AEOLUS Ground Systems.

Another example for enhancing on board autonomy is presented in paper AIAA 2010-1998: Geologic mapping of the Martian surface has been a goal for every mission to Mars in history. Surface rover missions bring with them unique capabilities and intrinsic challenges for the task of mapping. The diversity of the terrain that is encountered as a rover traverses is a challenge that is being addressed by two major mapping strategies: on-board autonomy and ground operations software. Here we present our latest work in the use of ground operations software that extends and enhances the work done in autonomy to provide accurate localization and mapping capabilities for rover missions.

On of the "best topic papers" of the SpaceOps2012 Conference, the paper "TDX-TSX-On-board and FDIR of whispering brothers" (AIAA-2012-1290887) addresses the integrated FDIR of the overall system taking utmost benfit of the distributed hierarchical FDIR and autonomy system design, while utilizing only minimum interaction between the two satellites.

On Orbit Constraints Test (OOCT)

On-Orbit Constraints Test (OOCT's) refers to mating flight hardware together on the ground before they will be mated on-orbit or on the Lunar surface. The concept seems simple but it can be difficult to perform operations like this on the ground when the flight hardware is being designed to be mated on-orbit in a zero-g/vacuum environment of space or low-g/vacuum environment on the Lunar/Mars Surface.

OOCT's performed on International Space Station (ISS) flight elements, lessons learned as a result of the OOCT's will be presented in the paper AIAA 2010-2369 and the paper will conclude with possible applications to Moon and Mars Surface operations planned for the Constellation Program.

Operations Reliability

During the 2016 conference this selected paper discussed the managment and reliabilit aspects of complex missions and their operations: Coping with Complexity and System Challenges in Safety and Reliability Management of Satellite Operations (AIAA 2016-2480).

Operations System Design

This new topic was introduced during the 2016 conference with the paper: A Structured, Model-Based Systems Engineering Methodology for Operations System Design by JPL (AIAA 2016-2502).
Paper AIAA 2018-2446 describes an evolution from a traditional satellite commanding Interface Control Document (ICD) to a service suite which provides real-time propagation and validation of interface changes.

On-Orbit Servicing (OOS)

On-Orbit Servicing as described in paper AIAA 2010-1975 is not only an option for the repair and the upgrade of space assets that suffer from technical failures but might also be a promising business case, e.g. extending the lifetime of geost ationary communication satellites.
The "best topic paper": "Operations for Parallel SatelliteSsupport" (AIAA-2012-1291254) describes the operatins challenges for the planned robotic dual-satllite DLR mission respecting operations experience gained during the ROKVISS and TanDEM-X missions.

Operations Tools

All software/hardware means used by the spacecraft operations personnel to operate a spacecraft as a system, including the payload, to achieve all mission goals. Classical operations tools are telemetry (TM), telecommand (TC), mission planning, orbit and attitude determination and control packages. It is suggested that the tools need not only integrate operations content but also life-cycle cost assessments for certain operations options to be used for final management decisions AIAA paper 2006-5751 . The use of not-yet-qualified operations tools is suggested for introduction into operations preparation activities as early as possible: The so-called “test as you fly” concept AIAA paper 2006-5713.

The SpaceOps2014 Conference added two new aspects to the use of operations tools:

AIAA 2014-1632: Space weather effects on spacecraft as an operational service to identify threads resultung from "the physical and phenomenological state of natural space environments.

AIAA 2014-1722: In this paper an "intelligent agent" to predict future failure occurrences onboard of spacevehicles using f Single Event Upsets in the Columbus mass memory as an example.

A standardized approach for operations audio alarms was discussed and appreciated during the 2016 conference:: Desgning and deploying meaningful audio alsrms for control systems AIAA 2016-2616 Another aspect for enhancing operations effectiveness is to use EGSE equipment for operations: The Operational Adoption of the EGS-CC at ESA (AIAA 2016-2304). A proposed plug-and-play" system infrastructure for robotic experiments was considered as one of the 2016 conference outstanding papers: The METERON Operations Environment and Robotic Services, a plug-and-play system infrastructure for Robotic experiments (AIAA 2016-2474). Data Mining as an operations tool was introduced withthe selected paper: AIAA 2016-2397: Data Mining to Drastically Improve Spacecraft Telemetry Checking: An Engineer’s Approach

AIAA 2016-2479 AMODS: "Autonomous Mobile On-Orbit Diagnostic System" presents an autonomous diagnostic and repair system for conventional and new satellites. AMODS is predicted to effect a paradigm shift in space operations.

Paper AIAA 2018-2532 focuses on the experiences of the Copernicus Sentinel-3 and EPS MetOp flight control teams in using the EUMETSAT CHART framework, which allows engineers to define automated reports and perform ad-hoc analysis on large datasets with multiple input sources.

Paper AIAA 2018-2561 presents an iterative and interactive pipeline framework which uses machine learning to predict, with more accuracy, the thermal power consumption.

Outreach Programs

Paper AIAA 2018-2437 provides some historical background on the ARISS program, it will describe the international volunteer team that is responsible for making this low-cost, high payoff program such a huge success, and will provide an overview of the proposal submittal, selection and contact preparation process

Paper AIAA 2018-2312 discusses the various Space-based STEM programs in South Africa that have been put in place to promote space education awareness and the contribution made by various role players like Universities, NASA and other Science related institutions.

P

Public Private Partnerships

Describes the combination of agency and industry resources and skills in a cooperative manner to reduce operations cost on the and possibly achieve market advantages. An example is New Zealand, which uses a PPP approach model very successfully to provide Government services (technology, hardware, bureaucracy, government markets) to private organizations contributing innovation, private investment and commercial markets. The application of this model is discussed for commercial space transportation for various scenarios (near earth, lunar exploration: AIAA paper 2006-5883 It is advocated that space business could grow by sharing the risk in PPP's according to similar models AIAA paper 2006-5932 .

R

Radiation Belt (Science Operations Planning)

The SpaceOps2012 Conference "best topic paper": Integral, An Investigation into Van Allen Belt and Geotail Crossings" (AIAA-2012-1346272) is offering an optimization strategy for science operations by predicting the evolution of radiation belt crossings and as a result, allow any protective measures to be implemented in time.

Requirements Tracing

The method by which to trace the realization of requirements from original establishment to the implementation and final acceptance by the customer. Requirements tracing is important for the design, implementation, qualification and acceptance processes. Complex systems (thousands of requirements and interfaces) require automated tools. A detailed description of an advanced tracing and verification tool incorporating the definition of test cases, procedures and status of test case mapping based on COTS was presented at the SpaceOps2008 conference at Heidelberg, Germany. The final tracing within a verification control data base (VCDB) as well as its methodology is demonstrated AIAA paper 2006-5877 .

Return on Experience (ROE)

The transfer of experience from previous missions to new projects for enhancement of efficiency, reliability and safety. This concerns not only the staffing of new projects with experienced people but also the capitalization of past experience gained in the design, development, qualification and/or operations of a relevant mission. Current experience is well published in SpaceOps symposia papers and presentations. "See AIAA papers: 2006-5800, 2006-5810 , 2006-5904, 2006-5919 , 2006-5955 and sub-sessions within the 2006 conference on “Operations Experience” and “Flight Operations Execution”.

The SpaceOps2014 Conference featured a couple of papers reporting lessons learned and tha appropriate return of experience. Six papers were selected to be outstanding providing information valid for future missions operations. The papers were:
AIAA 2014-1901: Two years of operations of the ChemCam instrument onboard the Curiosity rover.
AIAA 2014-1906: Drag-Free Attitude and orbit control system performance of ESA's GOCE mission.
AIAA 2014-1700: Lessons from 8 years of science operations of Venus Express.
AIAA 2014-1608: Extending the lifetime of ESA's X-ray observatory XMM-Newton.
AIAA 2014-1885: The Cluster mission after 13 years.
AIAA 2014-1935: The end of life operations of the Herschel Space Telescope
The SpaceOps2016 Conference contributed another ROE (best topic-) paper from CNES:
AIAA 2016-2611: Assessment of the Last Two STRATO SCIENCE Campaigns in Timmins, Canada

Refurbishment of Operations Systems

The "best topic paper" AIAA-2012-1263854 describes a method for migration from old to new hardare without interrupting 24/7 operations: A KISS (Keep It Simple and Stupid) design approach was taken resulting in a complete system replacement.

S

Science Operations

On of the selected "best topic paper" of the SpaceOps 2012 Conference was the "Efficacy of the Dawn Vesta Science Plan" (AIAA-2012-1275915), describing the results of the execution of the science operations plan and how that compared to the assumptions that informed the development of the plan.

Security (Communications)

Communications security for spaceflight means measures to keep the transmitted information from and to a spacecraft via the various communication links secure (confidential) and to prohibit unauthorized access to this information for the purpose of gaining this information and/or altering it. Security issues in spaceflight are very complex and not very highly published. One facet of security is user authentication: an ESA developed telecommand (TC) authentication scheme with a probability of discovering the key in the order of 1% is discussed. However this “discovering probability” is considered not to be adequate for specific ESA security requirements 2006-5580
More notable communications security considerations were presented during the 2016 Conference: AIAA 2016-2391: SpaceSecLab: A modular environment for prototyping space-link security protocols AIAA 2016-2525: Reliable Commanding and Telemetry Operations Using CFDP (CCSDS File Delivery Protocol)

Service Oriented Architecture

Service oriented architecture is a flexible set of design principles providing a system modelled as a loosely-integrated of services (2010-1922). Services are functional capabilities exchanged between service providers and service consumers within the system via well defined interfaces (2010-1903). Systems based on SOA are loosely related to OS and programming languages, which allows them to be easy to maintain and to manage (2008-3330). Interoperability, extensibility, adaptability and generic applicability are the key advantages of SOA-based systems. Basics of service oriented architectures and interactions of applications, components and infrastructure are presented (2006-5592 and 2008-3504). The CCSDS Mission Operation framework (CCSDSMO) based on a Service Oriented Architecture is introduced in 2008-3239. One paper advocates that higher integration of flight and ground aspects should be event driven not service driven to improve configurability and extensibility (2006-5531).

Simulators

Simulators are replicas of the entire spacecraft or components including mock up equipment to simulate (more or less realistically) real zero-gravity, in situ flight behavior. Simulators are used to check-out spacecraft functions on the ground and to train and qualify operations personnel pre-flight. During operations simulators are used for failure investigation and test of software reloads and/or new operations procedures.
Simulators have to tackle increasingly complex problems like satellite constellations and rover operations 2006-5972 , 2006-5973 , 2006-5974 , 2006-5975 . Simulators have a growing important role for knowledge-maintenance over long duration missions as as for public education 2006-5975
A future MARS system operational simulation was presented during the 2016 Conference and was selected as best topic paper:
AIAA 2016-2352: Future Mars System Operational Simulation: Research Outcomes and Educational Benefit

SLS (Space Launch System Program)

The NASA SLS program is charged with delivering a new capability for human and scientific exploaration beyond Earth orbit (BEO). This selected SpaceOps2012 Conference "best paper" (AIAA-2012-1272937) describes the current planning and components of this international program in detail, focussing on the opearions . An excellent summary showing how the Space Age continues to unfold. In the SpaceOps2016 Conference another SLS paper as "best.topic" paper was selected: AIAA 2016-2585: Enabling Science and Deep Space Exploration Through Space Launch System Secondary Payload Opportunities

Software Development

Method for developing flight and ground software under the specific aspects of uniqueness, functional verification, re-usability, adaptability, certification and maintainability during space-missions, respecting limited financial resources. AGILE programming as a new method to reduce overall S/W development cost in a mission control environment is recommended AIAA paper 2006-5701 . The use of complex and flexible telemetry/telecommand standard packages often do not yield the expected cost savings, because of high customization efforts (Round Table). The ESA Standardization Board has launched an ESA wide initiative aimed at standardizing Secure Software Engineering (SSE). The SpaceOps2014 Conference paper AIAA 2014-1799 describes this process. Another SpaceOps2014 paper describes an open source development for data integration and display with the core objective to enable collaboration, open the software to outside innovation and stimulate a community of open source mission operations participants and contributors (AIAA 2014-1762) . The ESA Ground Systems Common Core (EGS-CC) is theEuropean initiative to develop a common infrastructure to support space systems monitoring and control. The initiative is being performed as a collaboration between ESA, European national agencies and European industry (AiAA 2014-1767).

Space Settlement

In AIAA 2018 2410 a series of experiments is presented and analyzed which were carried out with 3D printers in a Mars Analog Simulation to investigate the operational benefit of 3D printing in human Mars missions. The experiments were part of a campaign called A3DPT-2-Mars.

Space Elevator

The Space Elevator is a cable extending 36,000 km from geosynchonous orbit (GEO) to the surface of the Earth. To hold up the cable there must be another large cable or counterweight extending upward from GEO such that the center of mass of the system is in GEO and orbiting with a velocity equal to the rotation rate of the Earth on its axis. People and/or machinery climb the cable (tether) from Earth's surface at an equatorial (sea/earth-) station in a cabin (climber) to GEO achieving orbital velocity. The first European Space Elevator Challenge (EuSEC) took place at the Technical University Munich, August 2011.

Spacecraft Operations

Spacecraft operations covers the preparation and implementation of activities to operate a space vehicle (manned and unmanned) under normal, non-nominal and emergency conditions. This includes the production and qualification of all means (tools, procedures and trained personnel) to perform this task.The main challenge is the cost-efficient combination of tools, degree of and staffing to provide secure and reliable operations. (see papers in the categories Automation, Planning Tools and Advanced Technologies, Earth Orbiting Missions, Moon Mars and Beyond, Operations Experiences).

SpaceOps Organization

The SpaceOps Organization is an association of international space agencies chartered in 1992 to foster continuous technical interchange on all aspects of space mission operations and ground data systems. The organization also promotes and maintains an international community of space operations experts from agencies, academic institutions, operators and industry.

Spiral Design

In a spiral development lifecycle, a process set is iterated and the risk is actively managed. The spiral emphasizes risk management in that, in each cycle, the first step is to evaluate products and process, identify risk and define the products of the subsequent iteration so as to minimize risk. As a result, the spiral software is effectively risk-driven in that risk analysis determines the products during each cycle. Spiral development thus differs significantly from repeatedly executing a sequence of linear (waterfall) processes blindly and with no risk assessment. Specifically, the win-win spiral development consists of the following steps during each cycle:

0. Identification of the stakeholders for the next software development cycle.
1. Identification of the criteria of success of each stakeholder. In general, stakeholder will use different criteria to assess whether the proposed software system is successful.
2. Reconciliation of success criteria.
3. Risk-driven evaluation of alternatives for processes and products, identification of the objectives for the next cycle.Plan execution.
4. Review and validation of product and process.

At the end of the cycle, either the product is complete or another cycle starts.(Vincenzo Liberatore “Scalability and Development of Space Exploration Networks”, Space Operations Communicator, July 2007)

Standard Actvities

The Consultative Committee for Space Data Systems (CCSDS) was formed in 1982 by the major space agencies of the world to provide a forum for discussion of common problems in the and operation of space data systems. It is currently composed of eleven member agencies, twenty-eight observer agencies, and over 140 industrial associates.Since its establishment, it has been actively developing recommendations for data- and information-systems standards to promote interoperability and cross support among cooperating space agencies, to enable multi-agency spaceflight collaboration (both planned and contingency) and new capabilities for missions.
Additionally, CCSDS standardization reduces the cost burden of spaceflight missions by allowing cost sharing between agencies and cost-effective commercialization. CCSDS also functions as *ISO TC20/SC13* (see below).

The International Organization for Standardization

(ISO) is the world's largest developer and publisher of International Standards. ISO represents 162 nations, and is composed of many technical committees and subcommittees. The two subcommittees (SC) focused on the space are under Technical Committee (TC) 20, Aircraft and Space Vehicles:
TC20/SC13 – Space Data and Information Transfer Systems.
The *Space Data and Information Transfer Systems Committee* is the ISO subcommittee responsible for standardization in the field of Space Data Systems. This committee has membership and scope overlap with CCSDS. Further, the TC20/SC13 standards document efforts consist exclusively of processing published CCSDS standards through the ISO system to produce standards that have the strength, authority and technical accuracy which results from both ISO and CCSDS processes.
TC20/SC14 – Space Systems and Operations.
The Space Systems and Operations Committee is the principal subcommittee responsible for standardization in the field of space systems

and operations. Founded in 1992, SC14 has a very broad scope with more than 80 projects underway. The scope of this group is standardization for manned and unmanned space vehicles, their design, production, maintenance, operation, and disposal, and the environment in which they operate.
The Object Management Group (OMG) produces and maintains industry specifications for interoperable enterprise applications. The Space Domain Task Forceof OMG consists of space professionals committed to greater interoperability, reduction in costs, schedule, and risk for space applications through increased standardization.

Standards

Accepted sets of definitions, which enable the user of those standards to exchange appropriate information in a seamless, cost saving manner. Presented spaceflight standards for ground and on-board are basically driven by the international Consultative Committee on Space Data Systems (CCSDS) and the European Space Agency ECSS standards.

CCSDS key words: layers, wrapabilty, swap ability 2006-5756 . Positive experiences with XTCE 2006-5582 are reported. Deployment of (CCSDS-) Space Link Extension (SLE) standards make quick process in Europe 2006-5667 2006-5668 , 2006-5732 , 2006-5767 , 2006-5597)– however it was noted that very few non-European papers were seen on SLE: is this as a consequence of Europe being ahead of other regions in SLE rollout? (Round Table) There is growing use of standardization, particularly SMP2 standard in simulators 2006-5974 . SMP2 is due to become an ECSS standard. ESA studies the unification of ground systems in Europe (standardization of interfaces) – is it recognized there is a long way to go 2006-5805 . Basic ideas for standardizing "Scientific Operations Systems" (SOS) are presented and are also proposed to CCSDS for establishing a working this subject 2006-5535 . Multi-mission operations concepts and their standardization must "go in one breath" (Round Table). There are lots of competing standards out there, suggesting the field is in a healthy state (Round Table).

Stovepiped

Describes the concept of customizing the design of the ground control systems to a particular satellite project. It is believed that the merging of those systems into an integrated system with the goal to operate all current and generations of the same group of satellites (e.g., military communication satellites) will make the ground command- and control system capabilites more efficient.

Stretch Goal Requirements

One of the Constellation program (-> Constellation) general policy states: A sustainable program (->Sustainable Space Exploration) hinges on how effectively total life cycle costs are managed. In response to the strong desire to manage the life cycle costs, special efforts were established to identify operability requirements to influence flight vehicle and ground infrastructure design. In order to impact the life cycle costs “stretch goal requirements” were introduced (2008-3308) into the Constellation Architecture Requirements Document (CARD).

Sustainable Space Exploration

Concept of an open architecture approach which would allow participation of commercial service providers and international partners and would incorporate new technologies as they are matured recommended to be applied for the Vision for Space Exploration (VSE).

In the SpaceOps 2016 Conference a paper from the Nigeria Space Agency (NASRDA)was selected as "best topic" paper:
AIAA 2016-2345: Quest of Nigeria into Space for Sustainable Development

System of Systems

Describes the concept of combining the results of similar spaceflight missions into an enhanced knowledge of the mission purpose on a global scale.

System Validation

The validation of the participating flight and ground systems in all possible configurations to validate the expected performance according to the specified system and subsystem requirements. This includes the flight and ground personnel as (i.e. end-to-end testing).
System Validation of all contributing ground subsystems is a precondition for operational qualification and is usually performed as an independent activity. Experience has shown that early system validation testing, in which the involved subsystems lack a common level of maturity, is beneficial.2
Paper AIAA 2018-2521 proposes a Model Base System Engineering approach to streamline Validation & Verification processes.

T

Time Distribution (Space Network)

Time distribution and synchronization in space networking are challenging due to long propagation delays, spacecraft movements, and relativistic effects, and therefore the Network Time Protocol (NTP) designed for terrestrial networks may not work properly. In this work, we consider a time distribution protocol that is based on time message exchanges similar to Network Time Protocol (NTP) but customized for the proximity space links such as the RF links between Mars orbiters and rovers. This protocol is called the Proximity-1 Space Link Interleaved Time Synchronization (PITS) protocol and is designed with goal of integrating with the CCSDS Proximity-1 Space Data Link Protocol's existing time capture capability. The PITS algorithm provides faster time synchronization via two-way time transfer over proximity links, improves scalability as the number of spacecraft increase, lowers storage space requirement for collecting time samples, and is robust against packet loss and misordering which underlying protocol mechanisms provide. The paper AIAA 2010-2360 describes the current progress of implementing and validating the correctness of the PITS algorithm at JPL, using the Mars Proximity link communications scenarios as our baseline.

Tracking Improvement

The Automated Transfer Vehicle (ATV) is an ESA project, as a European contribution to the International Space Station programme. This 20 ton cargo ship has been designed to supply the ISS. The ATV's way to the ISS is long and complex. The purpose of the paper AIAA 210-2213 is to present the Ariane 5 V181 telemetry network, including the radar network and its improvments for the first ATV flight. This paper also presents the real-time operations and the coordination of the ATV launch.

Training

One of the the 2010 "best papers" AIAA 2010-2223 describes how LCROSS prepared its flight team by deeply involving its operators in spacecraft and ground system design, implementation and test; leveraging collaborations with strategic partners; and conducting a spiral test and rehearsal program synchronized with the ground-up development of the ground system and spacecraft. Another "best paper" (AIAA-2012-1275405) introduces gaming principles to enhance computer-based self study of operations in long-duration missions. The SpaceOps2012 selected "best paper", "The ISS: A Unique In-Space Testbed as Exploration Analog" (AIAA-2012-1274874) proposes a ISS Testbed for Analog Research (ISTAR) by using the ISS to evaluate new exploration technologies, capabilites and operational concepts to better comprehend and mitigate human spaceflight risks - with real astronauts "in the loop".
Another SpaceOps2012 "best paper" focuses on "Multi-Mission Operator Training Practices" (AIAA-2012-1275361) combining the need for professional hires with an educational program for undergraduate students to be trained as certified command controllers.

Telemetry Compression

The "best topic paper": "Ten Times more information in your Real-Time TM" (AIAA-2012-1275117) describes an ESA method for compressing packets in real- time, i.e., each individual packet is compressed into an equivalent smaller packet as soon as it is generated, This opens up the possibility of increasing the information content of both the playback and real-time telemetry streams with a unique process at generation time significantly.

V

Vision for Space Exploration (VSE)

NASA’s long term goal as stated by former U.S President George W. Bush mandating “To implement a sustained and affordable human and robotic program to explore the solar system and beyond”.

X

XSearch

XSearch is a NASA search tool for flight controllers of the Space Shuttle and ISS to locate specific operations documents and records from among tens of thousands available in heterogeneous data bases (2008-3514). The system provides two other important capabilities: detection of cross-references and detection of textually similar records to facilitate safer and more effective mission operations.

Zot

Multiple detonations around the thruster injector due to fuel and/or combustion products condensing between thruster pulses and then igniting during a subsequent pulse. Coined by Marquardt Corporation from the BC comic strip that used the term to describe the result of a lightning strike. See for example Lipschutz, M., et al., "Failure Analysis of a Qualification Unit Injector for a Satellite Thruster", Proc. 24th Int'l Symposium for Testing & Failure Analysis, Dallas, TX, 15-19 Nov 98, pp83-91, and [available through Google Books]