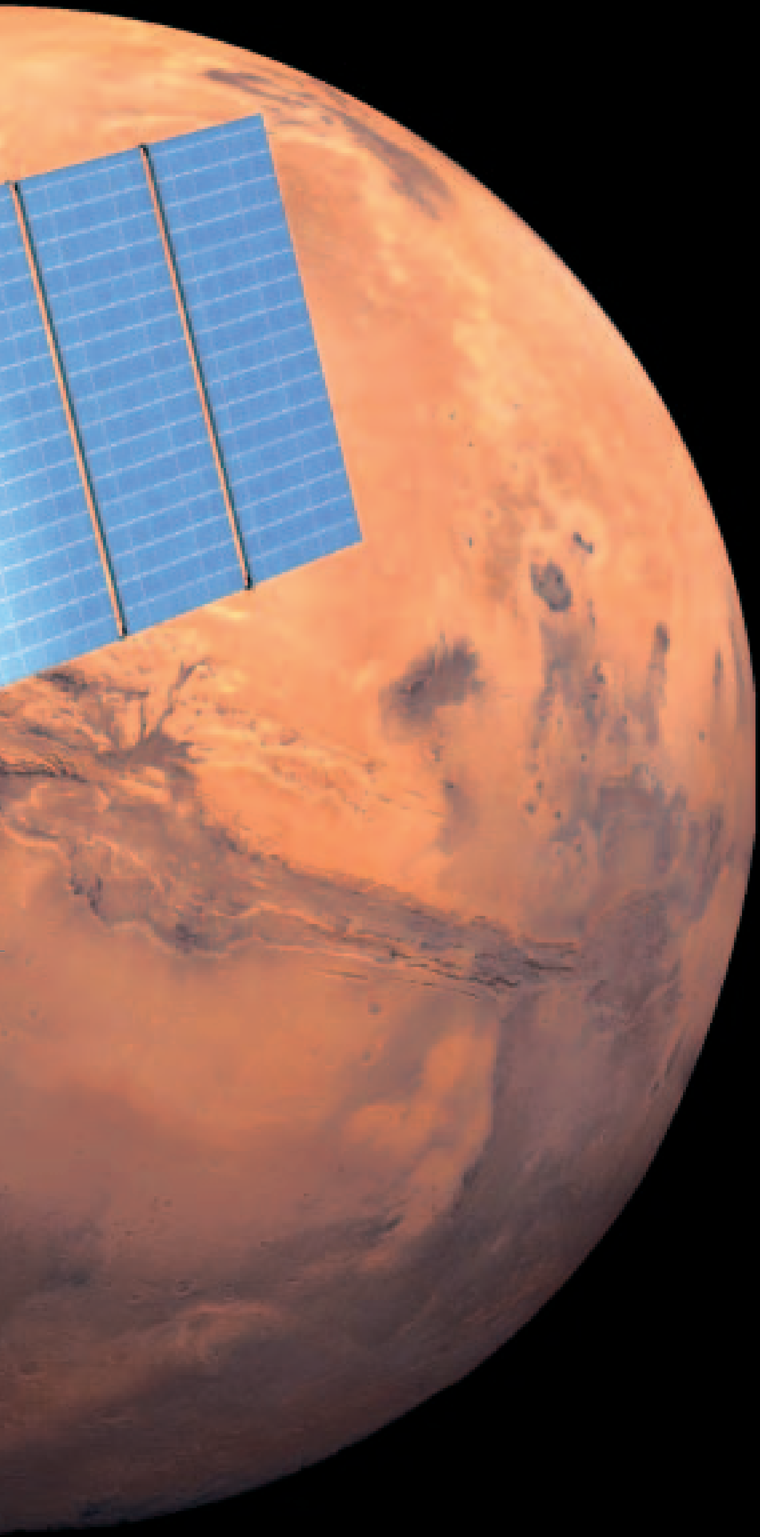
Engineering Standardization at ESA

– Improving technical quality and cost-effectiveness in space



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The importance of standardization for space activities in Europe is growing as the space agencies and industry are faced with new technical challenges within more demanding economic constraints. Missions and satellites have challenging performance and lifetime requirements; the technology is becoming more sophisticated, with more and more reliance on onboard intelligence and autonomy, while both schedule and costs have to be reduced. Engineering Standards contribute to the technical quality of the space products and the cost-effectiveness of the development and operations, thereby helping to make these achievements possible.

Why Space Engineering Standards?

Standardization is important to ESA and the space industry as a whole as they reach for new frontiers and strive to meet new challenges, but with the knowledge that their satellites need to be delivered on schedule and within budget and still be of very high technical quality.

Everyone knows that space missions are a risky business, where technology is pushed to the limit and the associated cost is significant. In addition, the space environment often does not offer the option of correcting problems that were not identified before launch. All this imposes a very strict approach to the engineering of the space segment, the mission element actually operating in space, and the ground segment.

For these reasons, space agencies and industry have invested in Engineering Standardization as a mean of reducing both the risk of failure and the development and operations costs. The risks are decreased because standardization offers proven and consolidated processes, methodologies and interfaces. Cost is reduced as standardization spreads the investment for technological developments across various space missions, and requires less-expensive test campaigns.

Furthermore, standardization typically supports interoperability: this means that if Standards are properly applied, the testing and operations facilities of several space agencies can be shared, thereby further reducing investment and maintenance costs.

An example of where a technical issue is overcome by the development of a standard can be found in the communications and data-handling interface between the space and the ground segments. Prior to 1994, new space missions basically re-developed each time the way of performing routine and troubleshooting operations and defined ex-novo the data structure of the telemetry sent from the spacecraft to the ground, and of the telecommands sent from the ground to the spacecraft. In 1994, the Packet Utilization Standard (PUS) was developed to define a common operational framework that is implemented via a standard set of monitoring and control services, each having a standard information model and data structures. Since then, most ESA missions, including all foreseen future spacecraft, use the PUS, with significant technical quality and economic benefits for both the space and ground segments.

Whilst standardization of technical processes can reduce the risk of anomalies and failures by using proven technologies, it also plays its part in determining the cost-effectiveness of a product or a process. Standards defining common procedures, interfaces or methods enable compatibility of technology in a specific sector or within a specialised domain, allowing industry to invest in fewer methods and tools, and reducing the development risks.

For businesses, the widespread adoption of Standards means that suppliers can base the development of their products and services on specifications that have wide acceptance within their sectors. This in turn means that businesses are able to compete in many more markets around the World. For customers, the worldwide compatibility of technology that is achieved when products and services are based on common Standards brings them an increasingly wide choice of offers, and they also benefit from the effects of greater competition between suppliers. For consumers, conformity of products and services to Standards provides assurance about their quality, safety and reliability.

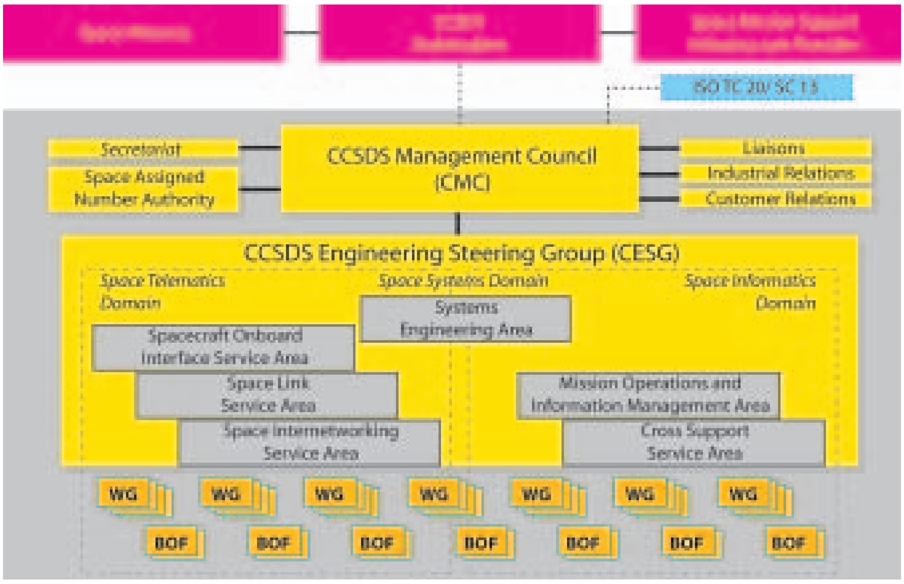
International and European Standards

As space exploration is a comparatively recent endeavour in mankind's history, engineering standardization has developed just over the last 20 years. Before that, the various space agencies were either developing their own internal or proprietary systems using no standards, or using internal standards that implied bespoke multiple developments and little interoperability.

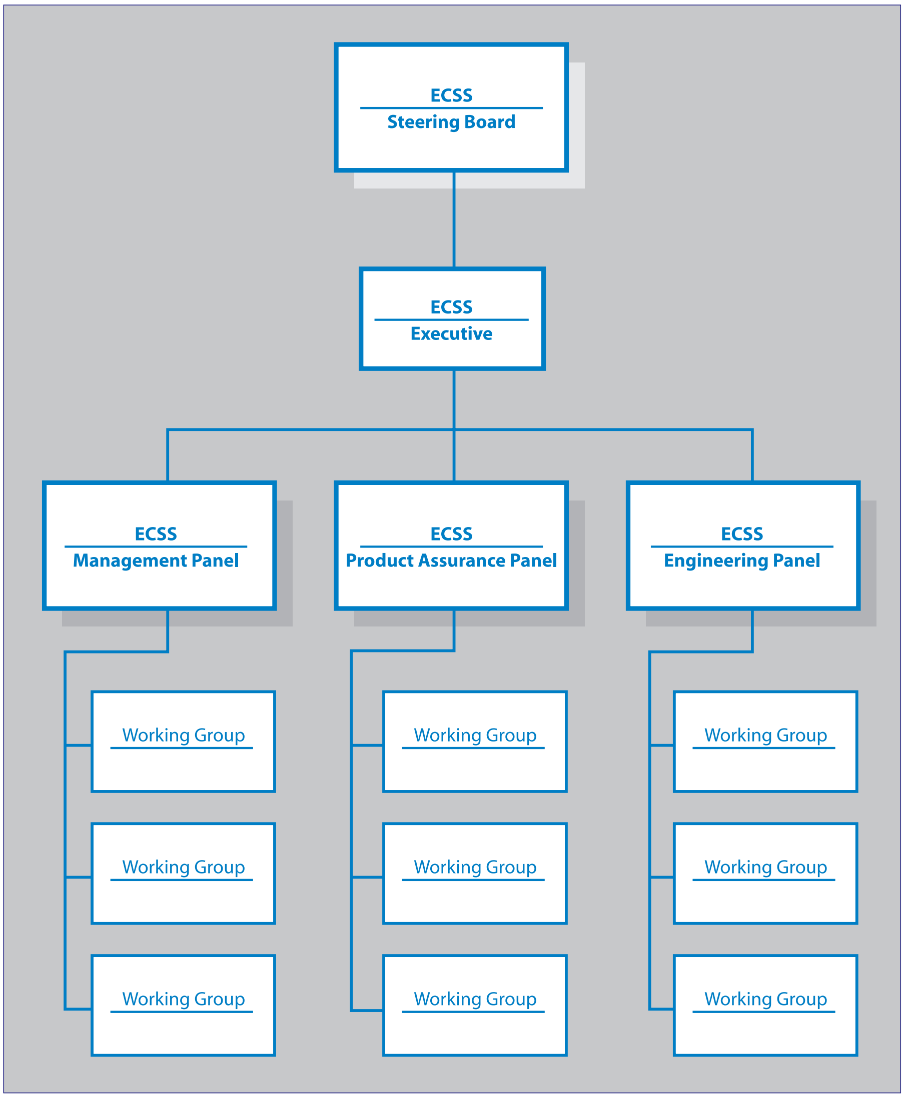
In 1982, ESA, NASA and CNES (France's Centre National d'Etudes Spatiales) established the Consultative Committee for Space Data Systems (CCSDS), an international standardization body intended to address communications and data-handling techniques for data-system interoperability and standardization of space-related information technologies. Today, CCSDS's membership includes no less than ten space agencies: Agenzia Spaziale Italiana (ASI), British National Space Centre (BNSC), Canadian Space Agency (CSA), Centre National d'Etudes Spatiales (CNES), Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), European Space Agency (ESA), Instituto Nacional de Pesquisas Espaciais do Brazil (INPE), National Aeronautics and Space Administration (NASA), National Space Agency of Japan (JAXA), and the Russian Space Agency (RSA). In addition, the CCSDS counts on several other participants in the form of observers, associates and collaborators. The CCSDS's recommendations, once approved, become International Organisation for Standardization (ISO) standards. The accompanying figure shows the body's high-level organisation and the breakdown into technical domains. Engineering work is mainly performed either within dedicated Working Groups for the development of Standards, or within 'Birds of a Feather' Groups for initial feasibility investigation.

The European Cooperation for Space Standardization (ECSS) (see accompanying figure) was established in 1993 to develop a coherent, single set of standards for use in all European space design and development activities. The set-up was devised in a spirit of true cooperation between the agencies and industry. Historically, the European space business had to support a multiplicity of different standards and requirements emanating from the various space agencies in Europe. Although the latter's requirements were essentially similar, the impact of these differences in standards was serious and led to higher costs, lower effectiveness and, moreover, a less-competitive industry. Input to the ECSS Standards comes from European space agencies and from industry. Initially, the thrust was mainly on Management and Product Assurance standards, but later Engineering standards were also addressed. ECSS Standards, once approved, are adopted as CEN (European Committee for Standardization) and ISO standards. The accompanying figure shows the main areas of standardization now covered by the ECSS.

Engineering standardization, which covers a very large technical domain in terms of processes, design techniques and interfaces, has been divided into seven separate space-engineering branches to cover the essential elements needed for space projects:



The structure of the Consultative Committee for Space Data Systems (CCSDS), showing the various technical domains addressed

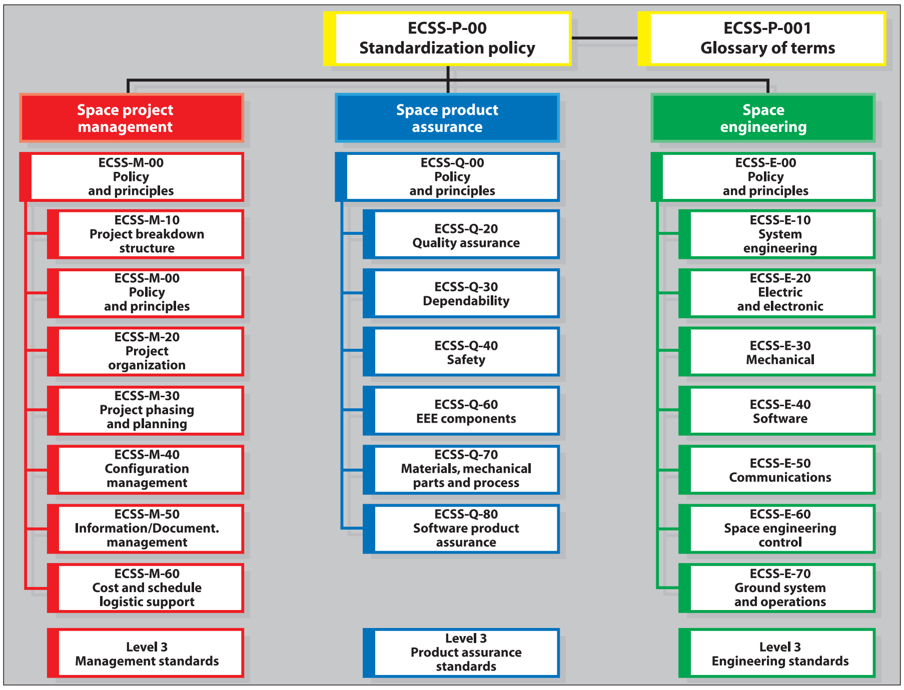


The structure of the European Cooperation for Space Standardization (ECSS)

• *System Engineering:*
Development has been undertaken by both the ECSS and the CCSDS. As an example, the System Engineering Process Standard, ECSS E-10 Part 1, is considered to be the keystone Standard for all space projects, as it introduces the system-engineering principles into a space-dedicated process and provides a process framework, modulated through all affected project phases. Several other ECSS standards covering inherent system-engineering aspects and disciplines, like verification, data exchange, mechanical engineering, software, communications, etc., refer to ECSS E-10 Part 1 as a process framework. Additionally, the CCSDS covers complementary Systems Engineering aspects such as data security and information modelling.

• *Electrical and Electronic Engineering:*
As an example, the Electrical and Electronic Standard, ECSS E-20A, establishes the basic rules and general principles applicable to the electrical, electronic, electromagnetic, microwave and optical engineering processes. Currently, a Standard on electromagnetic compatibility is being developed.

• *Mechanical Engineering:*
As an example, the Structural Standard, ECSS E-30 Part 2A, defines the requirements to be considered in all engineering aspects of structures: requirement definition and specification, design, development, verification, production, in-service and eventual disposal. Other topics covered are thermal control, mechanisms, Environmental Control and Life Support (ECLS), propulsion, pyrotechnics, mechanical parts and materials.



The main areas covered by the European Cooperation for Space Standardization (ECSS)

• *Software Engineering:*
As an example, the software standard ECSS E-40 covers all aspects of space software engineering, including requirements definition, design, production, verification and validation, transfer, operations and maintenance.

• *Communications Engineering:*
Covers space-to-ground communication. Standards development has been undertaken by both the ECSS and the CCSDS Space Telematics Domain. As examples, the CCSDS Packet Telemetry and Packet Telecommand Standards have been and are being used systematically by several spacecraft. The Radio Frequency and Modulation Standard, ECSS E-50-05, defines the radio-communication techniques used for the transfer of information between spacecraft and Earth stations in both directions, while the Ranging Standard, ECSS E-50-02, covers the tracking systems used for orbit determination. The Proximity-1 Space Link Protocols suite, CCSDS 211, covers the communication between the Earth and a lander on a planet via a spacecraft orbiting that planet.

• *Control Engineering:*
Covers the engineering guidelines for the control of space systems and ground control systems (if control loops are closed via the ground). Currently, the main fields of standardization are related to control performance and star sensors.

• *Ground Systems and Operations Engineering*
Covers ground facilities for mission operations (ground stations, mission-control centres, ground interconnection infrastructures) and ground-support equipment for spacecraft assembly integration and testing. Standards development in this branch has been undertaken by both the ECSS and the CCSDS Space Informatics Domain. As an example, the Telemetry and Telecommand Packet Utilization Standard, ECSS-E-70-41, addresses the utilisation of telecommand packets and telemetry source packets for the purposes of remote monitoring and control of subsystems and payloads. The Space Link Extension suite, CCSDS 911 and 912, provides a standard protocol between ground station and mission-control centre.

ESA and Standardization

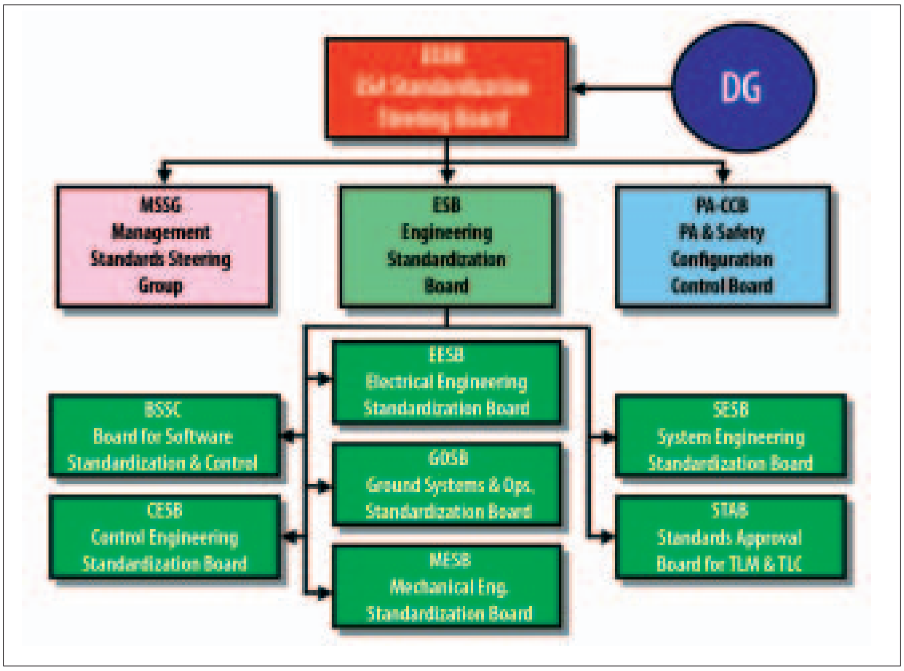
ESA is a major contributor to the European Engineering Standardization effort. Approximately 20 man years of effort are spent annually to support the related activities. ESA personnel participate at various levels of the ECSS and CCSDS organisations, to help guide the Standardization efforts and develop Standards within the various Working Groups put in place for this purpose.

The development of Standards is extended by a proactive approach to applying them in ESA projects and to improving them. ESA has in place a list of approved Standards applicable at large to all of its activities. The list includes mainly standards from the ECSS and CCSDS, and a few previously existing standards, e.g. Military standards (MIL-Std) and ESA Procedures, Standards and Specifications (PSS), which do not yet have an ECSS or CCSDS equivalent.

Within ESA, the coordination of standardization is the responsibility of the ESA Standardization Steering Board (ESSB), an inter-Directorate steering group mandated by the Director General to address the three branches of standards - Management, Product Assurance and Engineering - focusing on the support of space projects through standardization. This Steering Board is supported by the Engineering Standardization Board (ESB), which is responsible for identifying the standardization needs for ESA projects and contributing to the generation of relevant standards. The ESB is currently also involved in developing procedures for enhanced feedback on the utilisation of Standards by collating data gathered through the experiences of its members, and feedback from projects through lessons learnt, from agencies, and from industry. This ensures that Standards are not only being fully and correctly utilised by projects, but are also revised if necessary.

The ESB has formed the following sub-Boards in order to mirror the various space-engineering areas:

– Systems Engineering Standardization Board (SESB)
– Electrical and Electronic Standardization Board (EESB)



The organisation of Engineering Standardization in ESA

– Mechanical Engineering Standardization Board (MESB)
– Board for Software Standardization and Control (BSSC)
– Standards Approval Board for Telemetry and Data Handling (STAB)
– Control Engineering Standardization Board (CESB)
– Ground Systems and Operations Standardization Board (GOSB).

These sub-Boards are composed of ESA technical experts in the relevant fields and by project representatives, who ensure that space Standards developments are technically sound and meet the needs of the ESA projects. The experts on these sub-Boards, who come mainly from the ESA technical departments, also provide guidance and support on meeting the project requirements through the tailoring of standards. The sub-Boards are also responsible for recommending to the ESSB, via the ESB, the Standards that should be adopted by ESA and included in the List of Approved Standards. It includes only those standards that are applicable and to be used for all ESA space projects, and is maintained through feedback from the projects and industry.

Achievements

Major progress has been achieved since the time when each European agency and industry was using disparate sets of documents as standards. There is now a solid base of Engineering Standards, widely accepted by all European actors, which has been generated within the framework of the ECSS and CCSDS. Fifty such standards are in daily use by ESA. This represents the synthesis and the result of most of the cumulative experience of the European space actors, agencies and industry over the last decades.

A good example of ESA's achievements is in the fracture domain, where in the late eighties it initiated the definition of proper requirements, resulting in the issuing of one of the first Mechanical Engineering Standards. It was subsequently improved and issued as an ECSS Standard, E-30-01. It has now become the definitive Standard for this discipline for all ESA and many non-ESA projects. NASA has accepted it for application for Space Station (ISS) and Space Shuttle payloads, thereby simplifying the process of structural-integrity clearance for ESA/European payloads destined for Shuttle and ISS flights.

Thanks to the introduction of the CCSDS Proximity-1 Protocol, ESA's Mars Express mission was recently able to relay data to Earth from NASA's Mars Exploration Rovers 'Spirit' and 'Opportunity', overcoming the great distance between the two planets and the rovers' limited transmitter capability and allowing the scientific data return to be maximised. In future, any ESA, NASA, CNES or JAXA (Japan Aerospace Exploration Agency) Mars orbiter will be able to relay the telemetry data from any lander or rover from these agencies.

The benefit of standardization is also evident in the use of CCSDS Space Link Extension (SLE) services, which allows NASA Deep Space Network of ground stations to be used in support of ESA's Integral, Mars Express and Rosetta missions. This protocol between mission control centre and ground station facilitates the cross-support and maximises the performance and cost benefits to ESA projects.

Today, more than 300 space missions worldwide have applied the CCSDS- and ECSS-developed standards. All ESA missions currently under development also rely heavily on these standards.

Conclusion

Engineering standardization has proved itself to be an essential part of European space activities. It contributes to the achievement and improvement of the technical quality of space projects and products by optimising design solutions and reducing the risk of anomalies. Cost-effectiveness is also increased by the minimisation of development problems and the sharing of knowledge and common requirements. Through the ECSS and CCSDS organizations, today Europe has in place a strong base of Engineering Standards that span all of the technical fields involved in space-programme development and operations.

Future work is needed to consolidate and improve the existing standards and ensure the thorough coverage of all processes. New technologies and increased space system design complexity will also require the availability of new standards.

Further Information

For additional information visit:
- Consultative Committee for Space Data Systems (CCSDS), at **www.ccsds.org**
- International Organization for Standards (ISO), at **www.iso.ch**
- European Cooperation for Space Standardization (ECSS), at **www.ecss.nl**
- European Committee for Standardization (CEN), at **www.cenorm.be**

Coherent with its role in European space activities, ESA's continued proactive standardization involvement, both through the effective application of existing standards and in the development of new standards, ensures that all projects can benefit from its technical competence and experience accrued in numerous projects. It is also essential that other European space agencies and industry remain extensively involved in standards development and their effective application in their activities.

Clearly, Engineering Standardization has its cost, with funds needed to cover expert resources for development and prototyping activities as well as for participating in the standardization organisations. This is, however, an investment for the future, which should allow the successful completion of ever more challenging space missions and enhance the competitiveness of European space products.