Enhancing space data exploitation through advanced data routing protocols

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SPACE-DATA ROUTERS

http://www.spacedatarouters.eu

Abstract: Data sharing and access are major issues in space sciences, as they influence the degree of data exploitation. The project “Space-Data Routers”, which was initiated recently, has the aim of allowing space agencies, academic institutes and research centres to share space-data generated by single or multiple missions, in an efficient, secure and automated manner. The approach of “Space-Data Routers” relies on space internetworking – and in particular on Delay-Tolerant Networking (DTN), which marks the new era in space communications, unifies space and earth communication infrastructures and delivers a set of tools and protocols for space-data exploitation. The project has started with defining limitations currently imposed by typical space mission scenarios, in which the National Observatory of Athens (NOA) is currently involved, including space exploration, planetary exploration and Earth observation missions. Here we are presenting the mission scenarios and the associated major scientific objectives of “Space-Data Routers”, with an emphasis on the Sun-Earth connection and the Mars hyperspectral imaging spectroscopy scenarios. In the case of the Sun-Earth connection scenario, we plan to test and validate the capabilities of Space-Data Routers in providing: a) Simultaneous real- time sampling of space plasmas from multiple points with cost-effective means and measuring of phenomena with higher resolution and better coverage to address outstanding science questions and b) Successful data transmission even in hostile communication conditions. In the case of the Mars hyperspectral imaging spectroscopy scenario we plan to test and validate the capabilities of Space-Data Routers in augmenting the data volume received from Mars Express, through the increase of Mars Express connectivity with ground stations and through the increase of access speed to the hyperspectral data depository.

Today, Space-Data exploitation faces two major obstacles:

- The limited access to scientific data since their connectivity time via satellites directly confines their scientific capacity.
- The lack of sufficient mechanisms in Space-Data Collection Centres for communicating with interested end users, let alone the lack of mechanisms for data dissemination.

➔ resulting in stored and unexploited space data, until they become obsolete or useless and being removed.

(In Space-Data exploitation, the situation is expected to worsen: Space data volume will increase (i.e. Sentinel missions), while the mechanisms for disseminating and exploiting data are not yet in place.)

The effective and efficient exploitation and dissemination of space data should not be considered as a peripheral issue, but as an urgently-missing mechanism from the European Infrastructure

The basic aim of “Space Data Routers” project (SDR) is to allow Space Agencies, Academic Institutes and Research Centres to share space-data generated by a single or multiple missions, in a natural, flexible, secure and automated manner. In particular, SDR will:

- ❑ boost the dissemination capability for Space Data on Earth by extending end user access to space data through communicating Ground Stations and Space Research Centers,
- ❑ allow for exploiting Data from Deep Space and disseminating it naturally through unified communication channels,
- ❑ exploit European Scientific Capacity as well as ESA’s existing infrastructure, resources, protocols policies and assets,
- ❑ allow for cross-mission scientific applications, by demonstrating the capability of the DTN space-data overlays to administer thematic cross-mission space-data.

The proposed approach relies on space internetworking – and in particular in Delay-Tolerant Networking (DTN), which marks the new era in space communications, unifies space and earth communication infrastructures and delivers a set of tools and protocols for space-data exploitation within a single device. Space-Data Router implements a dual role: It increases communication flexibility in Space and forms a mission-/application-oriented communication overlay for data dissemination on Earth.

The following scenarios in particular aim to demonstrate the potential of exploiting data from deep space and disseminate it naturally through unified communication channels :

❑ Sun-Earth connection

The term “space weather” refers to conditions on the Sun and in the solar wind, Earth's magnetosphere, ionosphere, and thermosphere that can influence the performance, efficiency, and reliability of space - and ground-based infrastructure and can endanger unprotected humans in space conditions or above the Earth's poles. Nowadays, information from a single spacecraft vantage point can be replaced by multi-spacecraft distributed observatory methods and adaptive mission architectures that require computationally intensive analysis methods. Future explorers far from Earth will be in need of real-time data assimilation technologies to predict space weather at different solar system locations.

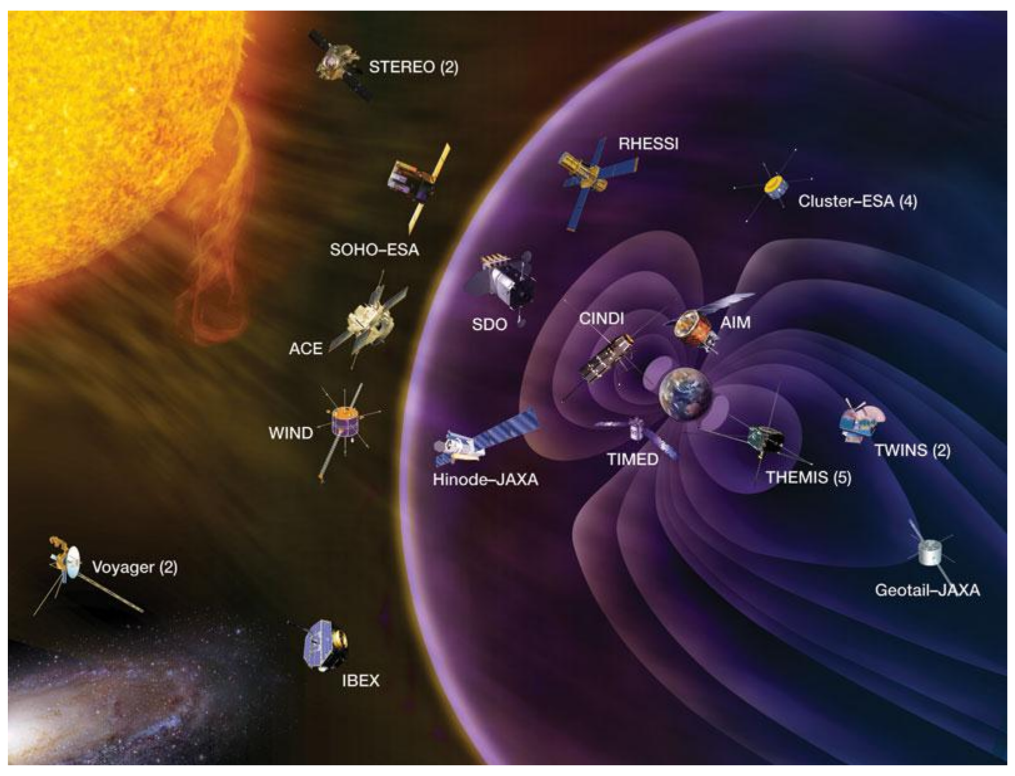

Figure 1. Schematic representation of all currently operating Heliophysics missions (credit: NASA)

The objective of this scenario is to now-cast and, ultimately, forecast the influence of solar disturbances (which propagate through interplanetary space and impinge on the terrestrial magnetosphere) on the development of electromagnetic waves in the magnetosphere and the wave effect on radiation belt variability.

We plan to test the capability of Space-Data Routers to efficiently distribute to registered end-users the relevant data streams from the two current NASA missions (ACE and THEMIS), an ESA mission (Cluster) and an upcoming NASA mission (Radiation Belt Storm Probes).

Expected impact using SDR:

The main requirements for this application scenario are the real-time availability of electric field, magnetic field and charged particle data as recorded by multiple missions in geospace and in the solar wind. The use of the DTN architecture could provide/improve:

- ❑ Real-time data acquisition from multiple missions for monitoring ULF/VLF wave occurrence and its effects on radiation belt dynamics.
- ❑ Successful data transmission even in harsh/challenged communication conditions.

❑ Hyperspectral images captured by OMEGA on-board ESA’s Mars Express satellite

Hyperspectral images are captured by *OMEGA* on-board ESA’s *Mars Express (MEx)* satellite. Data are processed for research purposes by NOA/ISARS. Currently, data are available online through ESA’ Planetary Science Archive. MEx is the first 'flexible' mission of ESA's long-term science exploration programme. MEx is still operating and data is still being harvested. More specifically, MEx is expected to:

- ➢image the entire surface of Mars at high resolution (10m pixel size) and selected areas at super resolution (2m pixel size),
- ➢produce a map of the mineral composition of the surface at 100 metre resolution,
- ➢map the composition of the atmosphere and determine its global circulation,
- ➢determine the structure of the sub-surface to a depth of a few kilometres,
- ➢determine the effect of the atmosphere on the surface,
- ➢determine the interaction of the atmosphere with the solar wind.

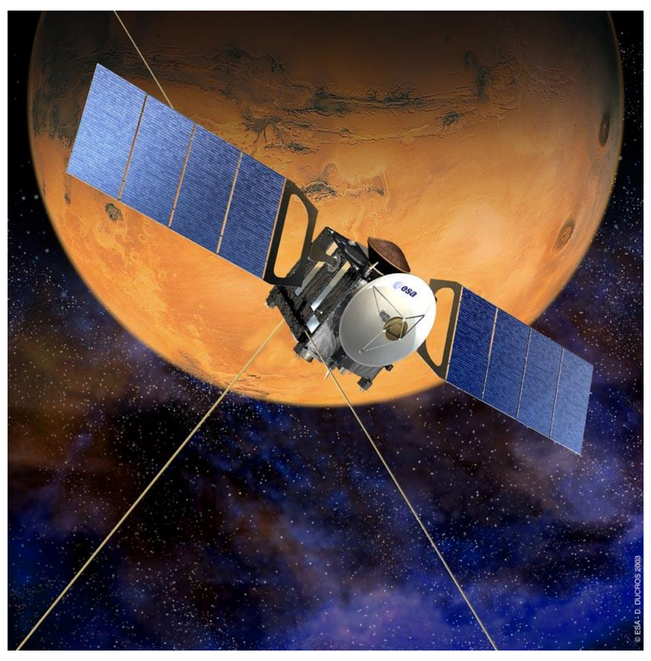

Figure 2. Illustration of Mars Express satellite (credit: ESA)

Expected impact using SDR:

If other ground stations were available, the total downlink science data volume would increase. The use of a second ground station for scientific data downlink, constitutes an opportunity for additional downlink time that would contribute to fulfil the initial scientific objectives of the mission. OMEGA is one of MEx’s instruments that would particularly benefit from the use of a second ground station due to the large volume of the hyperspectral cubes. The request for a second ground station for MEx has been approved and implemented. The Madrid NASA’s DSN station is essentially used as second ground station for MEx, offering 4 to 6 hours extra downlink time per day. Thus, the use of the SDR architecture for MEx OMEGA data is expected to:

- ❑ Increase the data volume received from Mars Express, by increasing the connectivity of Mars Express with ground stations.
- ❑ Provide access to current (possibly raw) image cubes.
- ❑ Increase the access speed to OMEGA hyperspectral data.

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