Mission Operations and Information Management Area
Spacecraft Monitoring & Control Working Group

Prepared by
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Working Group Goals For This Year (1 of 3)

Date: 27 January 2005

- **GOAL 1:**

4 April 05	Due to many review comments, the Green Books will be updated and available for re-review by CCSDS.
15 April 05	Submission of Green Books to CCSDS for approval

(Green Books are CCSDS Reports)

- **GOAL 2:**

Target Date 4 April 05	**Initial set of 4 New drafts of the Red Books as follows:** • SM&C **Protocol**: update with received comments • SM&C **Common Services**: update with received comments and expand the service specification • SM&C **Core Services**: update with received comments and expand the service the information model • SM&C **Time Service:** (target objective):produce initial draft following Template of Core Services.
1 Sept. 05	Availability of the "solid" versions of the 4 Red Books
16 Sept. 05	Submission of 4 Red Books to CCSDS for public review
Spring 2006	Availability of the 4 Blue Books

(A Red Book is a Draft Recommendation released for formal review)
(A Blue Book is a CCSDS Recommendation)

- **GOAL 3 (XTCE Review)**

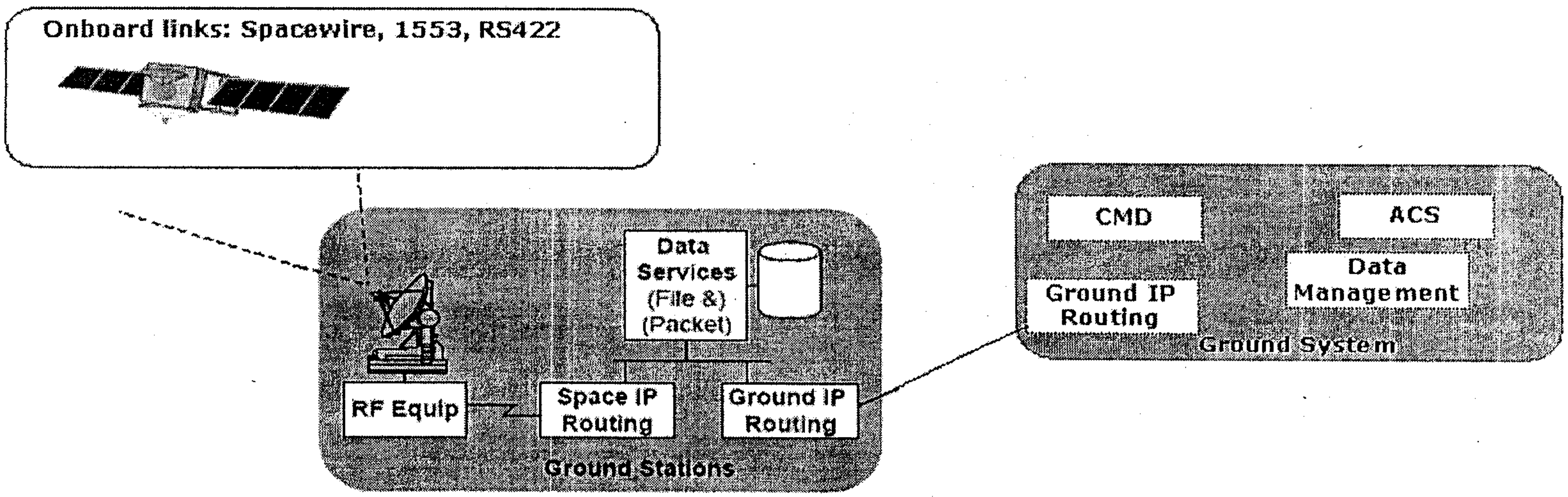
  We received the CMC approval for the XTCE review and negotiation has already started with OMG to finalize the details of the review process. It is anticipated that the XTCE Review will start soon. Based on this assumption, the following schedule was agreed:

15 February 05	Submission of XTCE review data package to CCSDS Secretariat for initiation of the Public Review
16 Sept. 05	Availability of reviewed XTCE document. (subject to review comment complexity)

XML **T**elemetry & **C**ommand **E**xchange Standard**:** is a standard for encapsulation of data in a descriptive manner used in spacecraft and their command and telemetry data systems.

THE FACTS OF SPACE - SYSTEM LIFE:

The Spacecraft	The Ground Station(s)	The Ground Processing system(s)
may be designed, built, and tested by one entity in one time frame using then-current flight technology by an "agency":	may be designed, built, and operated by various "agencies" long before launch, through and beyond splashdown, with: *periodically upgraded technologies:*	may be designed, built, and operated by other "agencies" in yet another part of the world, by people using different languages, possibly processing historical data long after spacecraft end-of-life with *periodically upgraded technologies:*
For example: A JPL Spacecraft	*Canadian, ESA, or BNSC Ground station*	*Telemetry forwarding/monitoring by Canada to ESA*



←========= COMMANDS {infrequent}

TELEMETRY ========→ {only when in sight of station(s) and scheduled}

The Spacecraft Monitor Control Protocol (SMCP) Specifications

(adapted from the RED BOOK, January 2005)

- The challenge of end-to-end monitor and control is that the end-to-end network is extremely heterogeneous:
  - A space network consists of TCP/IP running over several Ethernet links and RF links, transporting spacecraft messages from inside spacecraft to final data users' archiving systems.
- These messages vary in format and syntax between the member agencies.
- Thus for "agency" collaboration, this SMCP will standardize the telecommand and telemetry messages end-to-end.
- S/C Monitoring & Control Protocol **isolates** the spacecraft monitor (telemetry) and control (command) **applications** from underlying communications protocols.
  - This results in standard communication patterns and standard control patterns for communication between applications.
  - This is a "*Target-Controller*" pattern, performed by a string (or a network) of explicitly coupled elements.
- **Note that participation in the CCSDS is voluntary. The results of Committee actions are termed recommendations and are not binding on any Agency.**

- Each class of service will have its own application specific messages that are passed via the generic Monitor and Control Protocol Service. A spacecraft monitor and control context should define interfaces such as:
  - Spacecraft sub-systems <u>telemetry monitor</u> & sub-systems <u>control</u>
  - Spacecraft Instrument management, command and control
  - Spacecraft data link <u>telemetry monitor</u> and <u>spacecraft data format and transmitter control</u>
  - Spacecraft Flight Software management and control
  - Ground station antenna link monitor and Radio Frequency control
  - Control Center Flight algorithms & parameter management and control
  - Control Center Flight recorder Storage management and control, synchronized with ground station contacts
  - Ground data processing, data display conversions, archiving, history recovery
  - Telecom system management and control among all operations
  - Directive management, execution & control for all of the above links

These Standards are Appropriate through All Spacecraft Phases

1. Payload integration and qualification:
   - Early debugging of systems reduces future schedule risk.
   - Merging flight data with vibration table or thermal/vacuum data provides time-correlated results, particularly when anomalies occur.

2. Spacecraft integration & qualification: Has the same advantages as above.

3. Launch vehicle integration & qualification: Has the same advantages as above.

4. Launch Operations: All output displays can be the same as used above and as will be used though on-orbit life, to reduce operator training.

5. Flight operations control centers: Has the same advantages as above.

A Proposed Coherent and Consensus NASA/US Position to the SM&C Working Group

By Donald C. Lokerson, Amalaye Oyake, Peter Shames, and Ashton Vaughs

1. We have studied, learned, reviewed, commented, and often re-reviewed with comments the following documents:
    - SM&C Framework
    - SM&C Core Services
    - SM&C Common Services
    - SM&C Protocol

2. We concur with the Working Group Charter:
   The high level goal of this standardization effort is to make economies by:
   a) allowing interoperability with partner systems and infrastructure.
   b) reducing the risk of space missions by re-using systems and operational concepts, thus increasing their reliability.
   c) facilitating the development of generic (infrastructure) on-board and on ground software that can be shared by multiple projects via simple re-configuration.
   d) applying the SM&C approach and systems throughout all mission phases and to other M&C domains (e.g., ground stations, control centers, test facilities, etc.).

Working Group Issues to Consider (1 of 4)

- We should consider how to incorporate spacecraft technology upgrade transitions with these standards, such as when some heritage flight hardware is mixed with Spacecraft Monitor and Control protocol compliant hardware, such as the widely used flight 1553 busses that could be interfaced to the 1553 "controller" to make a hybrid partially-compliant system.

- These Standards are intentionally vague about the range of applications appropriate to these standards. Using such standard systems for launch vehicles and launch operations systems should be considered.

- NASA's vision for Lunar and Mars exploration will require inter-agency interoperability in space. The Transformational Communications Architecture is being developed by the DoD, NOAA, and NASA. Are these specifications a part of these plans by the multiple agencies?

Working Group Issues to Consider (2 of 4)

- This Working Group has personnel using ~7 different native languages. With the technical terminology (and extensive acronyms) used in these documents, real-time "translation" may create some different interpretations of the wording. Language differences could complicate remembering all of the acronyms in the document. Consider the need for translation services.

- A competing relevant spacecraft development at NASA by JPL and GSFC has flight-like 1394 Data Bus prototyping activity for the NOAA Preparatory Project, the next generation of NOAA spacecraft, and JPL's "Jupiter Icy Moons Orbiter Mission".

- European Space Agency already has a modern M&C core infrastructure named SCOS-2000. SCOS-2000 is a generic spacecraft mission monitoring and control infrastructure developed by ESA. It is a consistent end-to-end application for use by ESA members. How well does it mesh with these new standards?

Working Group Issues to Consider (3 of 4)

Other Relevant JPL Issues (1 of 2)

- XML is used in some mission settings. To ensure the completeness of XTCE it would be good to COMPARE XTCE against what is already in use, and report to this W.G. {submitted by Amalaye Oyake, JPL}
  - Agencies <u>should</u> review existing field tested Schemas INTERNAL Agency XML (CNES, JPL, ESA, JAXA) Schemas/DTDs used for M&C, Telecommand and Telemetry. Compare these field tested Schemas to XTCE wherever possible (usage, content).
  - Examine XTCE lower level data formats like: Time, Location, etc.
  - ENFORCE consistent representation between underlying data formats (Time, Location, Ephemeris, etc) in ALL Schemas in use within CCSDS (NAV, XTCE etc.). This will mitigate a myriad of schemas and the conversion tools needed to convert between them.
  - As much as possible, *all our schemas should be related to each other.* The elegant way to adopt schemas is to make sure they use the SAME underlying representations for the most BASIC elements (Time, Location, Ephemeris, etc), and the specific elements in the new schema. Since these low level elements are included (e.g. TimeRepresentation.xsd), any changes to them would be propagated consistently.

Working Group Issues to Consider (4 of 4)
Other Relevant JPL Issues (2 of 2)

- As a near term goal, ESA feels that they can achieve sufficient return on investment by using an adapter pattern (Common services and Core Service Redbooks).
  Whereas JPL feels that for long term goals, a low level M&C protocol should be created (SM&C Protocol Redbook).

- There is ongoing **D**eep **S**pace **N**etwork Reengineering work, and JPL must ensure that the efforts in this work are reflected in the Common and Core Service Redbooks.

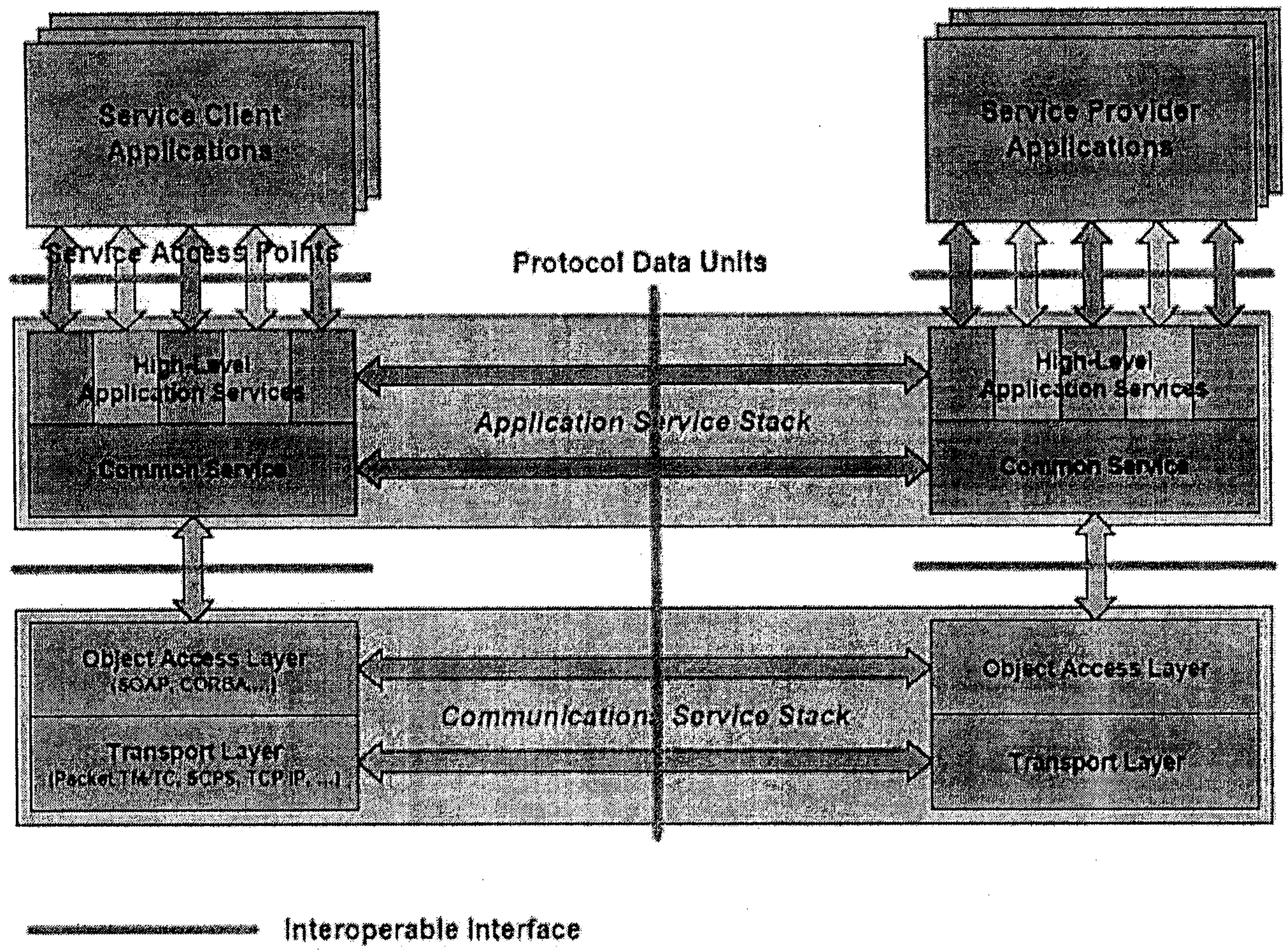
- There is an ongoing discussion about onboard messaging, concerning the CCSDS **M**essage **T**ransfer **S**ervice **A**pplication **P**rogramming **I**nterface and a new Asynchronous Messaging Protocol.

- There is ongoing work to try and produce a Plug and Play draft white book which will capture the work on Device Classifications and Plug and Play paradigms (hot-plug, warm-plug, cold-plug, etc).

THE END

BACK-UP SLIDES

CCSDS Core and Common Service Redbooks



The Transformational Communications Architecture being developed by the DoD, NOAA, and NASA

- In late 2002 Undersecretary of the Air Force Peter B. Teets unveiled plans... to ensure communications compatibility among several key organizations.

- The Transformational Communications Office will make it easier for DoD, the intelligence community and NASA to communicate with each other.

- A single integrated, synchronized communications network consisting of both satellite and ground capabilities. Also called, the "Internet in the Sky".

ESA: SCOS-2000, the generic spacecraft monitoring and control infrastructure

(55 licenses granted in Europe in the last three years)

- To reduce both risk and cost, the division bases its developments on mission data infrastructure, following a policy of reusing software.

- The main mission data infrastructure systems are for MCS: SCOS-2000:
  - mission control system kernel and, for simulation, the SIMSAT package.

  The Infrastructure Data Systems Division provides these infrastructure systems.

  The Mission Data Systems division works closely with this division, in particular, by providing feedback and help planning infrastructure evolution or new infrastructure.

(Slide 1 of 2) **Examples of where these Standards are intentionally vague about phase of S/C mission:**

From the Protocol Spec: Section 1.2:

For example:

- TCP/IP is used between the ground system and the ground station
- CCSDS Transfer Frames over an RF link is used between the ground and a spacecraft.
- Formatted bus messages (1553, VME) are used between the central data handling subsystem and other onboard subsystems.
- CFDP over an RF link is used between two spacecraft in close proximity.

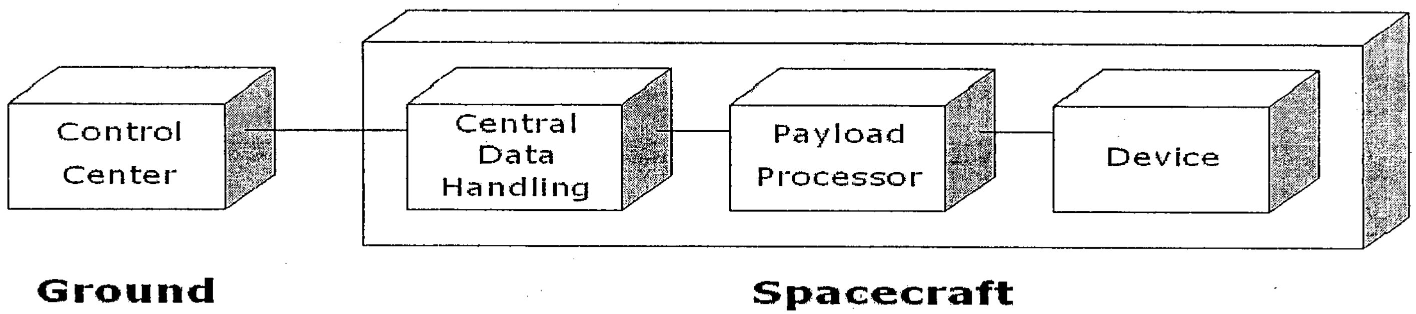
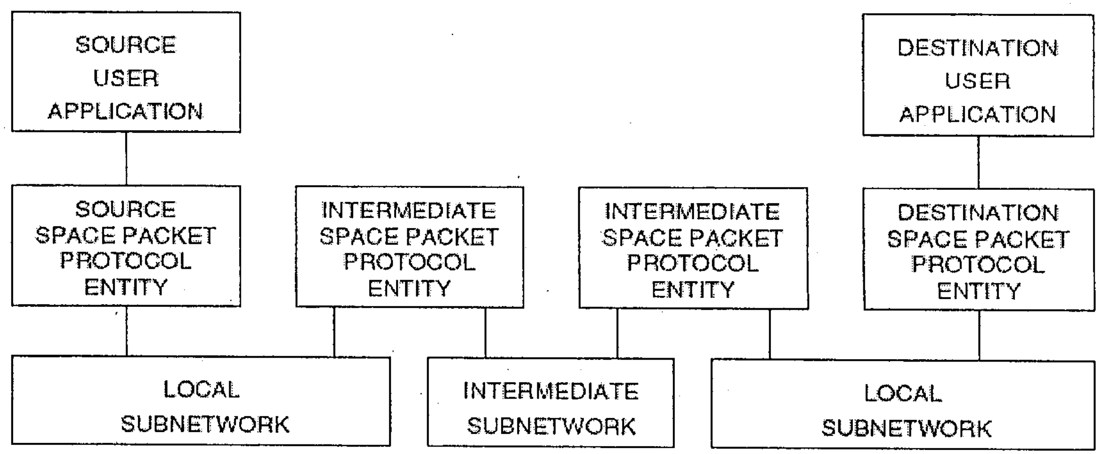


Figure 1.1

(Slide 1 of 2) **Examples of where these Standards are intentionally vague about phase of S/C mission:**

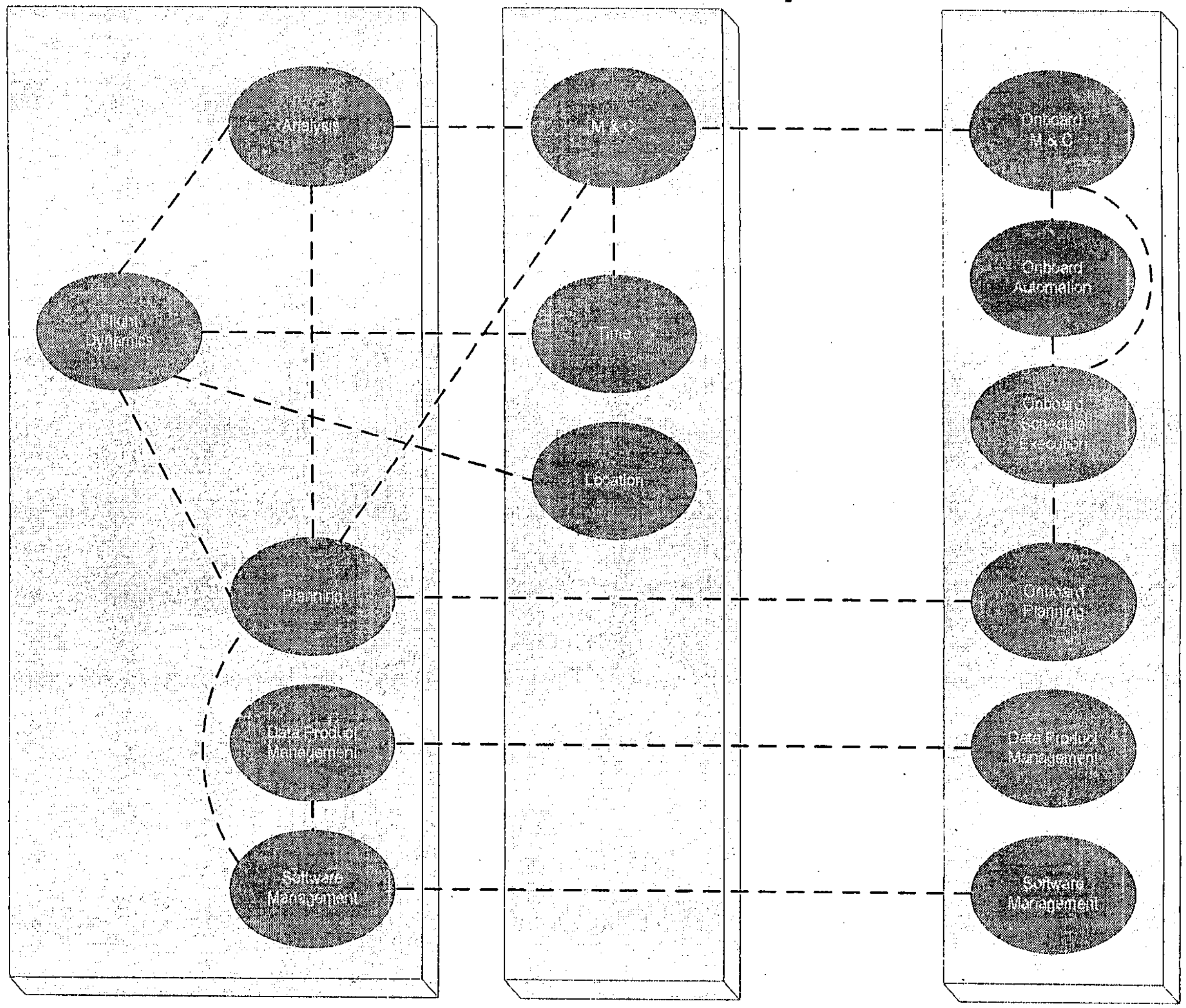


From the CORE Spec: Section 2.2.1

The Core service includes both basic and advanced capabilities. Basic capabilities correspond to those typical in the majority of existing spacecraft systems. Advanced capabilities correspond to optional features which nevertheless relate to the same fundamental data items.

The concept is intentionally independent of the location of the processes required to service it. In this regard, it may be that all aspects of processing associated with *monitoring parameters*, *actions* and *alerts* are located within the remote system itself, or it may be that some of the associated processing is performed within a ground-based proxy component that provides client access to these data items. For example status monitoring (the evaluation of predefined status checks) may be performed on-board a spacecraft or on-ground, but operationally, the client sees the result of these checks irrespective of where they are performed.

Mission Operations Services Concept: WHITE BOOK July 2004

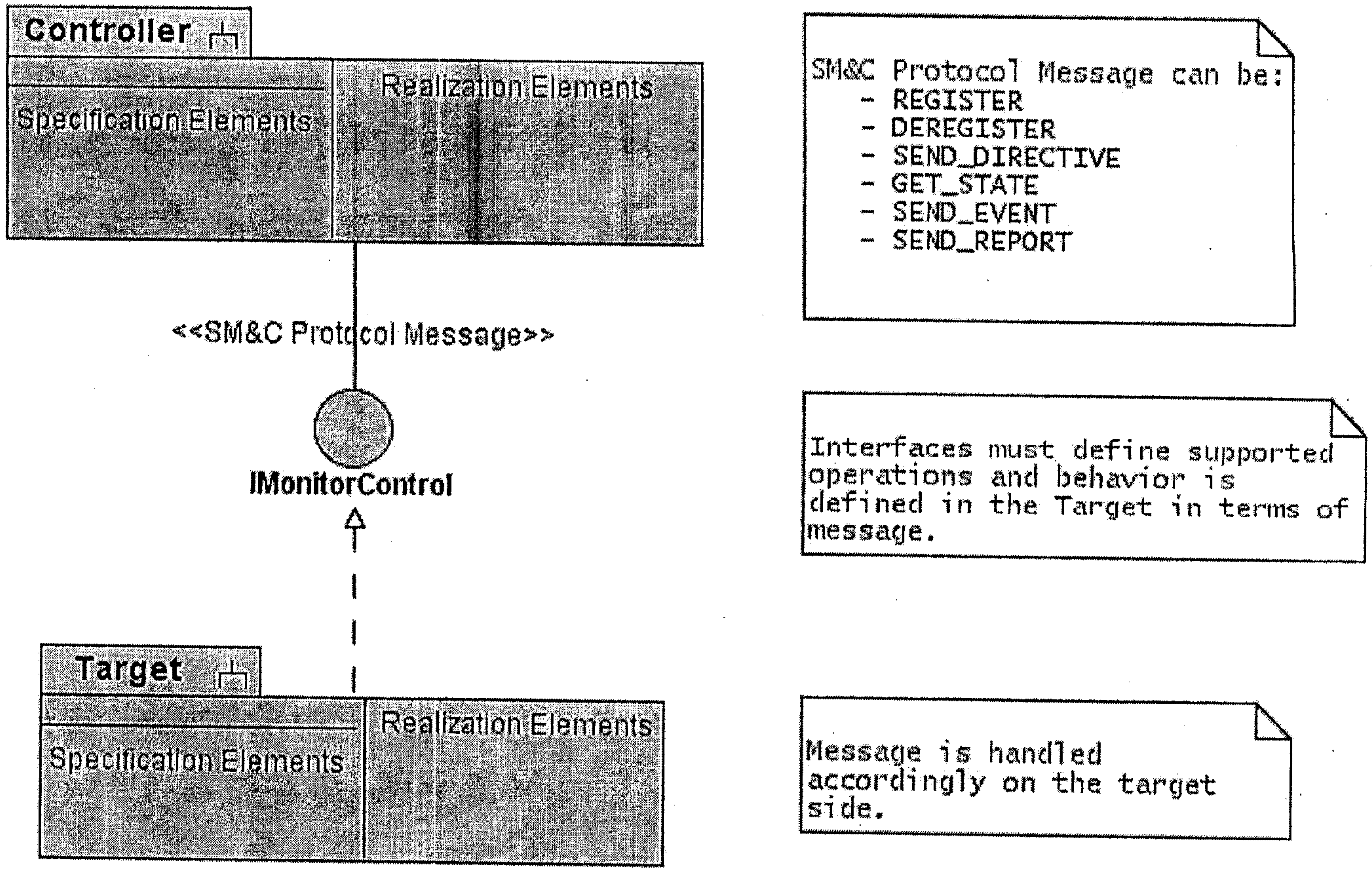


SM&C Protocol Redbooks

- The Spacecraft Monitor and Control Protocol (*SMCP*) is an application-level protocol for commanding a spacecraft, spacecraft subsystems and packaging spacecraft telemetry messages.

- End-to-end space networks consist of highly heterogeneous links with various message formats flowing over these links. Furthermore spacecraft message formats vary from mission to mission.

- SMCP is envisioned as a generic protocol with possible extensions for state interactions and system constraints. SMCP will define mechanisms for transport over different types of physical links.


Controller
Specification Elements
Realization Elements
<<SM&C Protocol Message>>
IMonitorControl
Target
Specification Elements
Realization Elements
SM&C Protocol Message can be:
- REGISTER
- DEREGISTER
- SEND_DIRECTIVE
- GET_STATE
- SEND_EVENT
- SEND_REPORT
Interfaces must define supported operations and behavior is defined in the Target in terms of message.
Message is handled accordingly on the target side.