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DOCUMENT

Proposal for a Telescope Commanding and Scheduling Data Standard

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CHANGE LOG

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Issue 1	1	0	2015-12-10
Changed name of “metadata” elements within “command”& “scheduleRequest” elements to “blockMetadata”, since they don’t contain the same content as the first level “metadata” element. Changed “exposure” segment in “scheduleRequest” to “not mandatory” (as in “command”). Added comments to use of multiple “dateTimeConstraint” or “nightConstraint” elements.	1	1	2015-12-22

CHANGE RECORD

Issue 1	Revision 1		
Reason for change	**Date**	**Pages**	**Paragraph(s)**

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1 TERMS, DEFINITIONS AND ABBREVIATED TERMS

1.1 Symbols and Abbreviations

n.a.	not applicable

Table 1: Symbols

ASCII	American Standard Code for Information Interchange
ASCOM	Astronomy Common Object Model
AstDyS	Asteroids Dynamic Site
CCSDS	Consultative Committee for Space Data Systems
CDM	Conjunction Data Message
ESA	European Space Agency
ESO	European Southern Observatory
FITS	Flexible Image Transport System
IAC	Instituto de Astrofísica de Canarias
INDI	Instrument-Neutral Distributed Interface
JSON	JavaScript Object Notation
NEO	Near Earth Object
NEODyS	Near Earth Objects Dynamic Site
OCA	Observatoire de la Côte d'Azur
OGS	Optical Ground Station
RTML	Remote Telescope Markup Language
RTS2	Remote Telescope System 2nd Version
SSA	Space Situational Awareness
TBT	Test Bed Telescope
TLE	Two-line element
TSM	Telescope Scheduling/Command Message
VLT	Very Large Telescope
XML	Extensible Markup Language

Table 2: Abbreviations

1.2 Terms and Definitions

Telescope Command File

Also referred to as "observation plan". Data file used to control a telescope. Contains absolute information on actions the telescope shall perform, e.g. absolute times and sky coordinates for observations. Telescope command files are read by a telescope control computer that still processes part of their content (e.g. conversion of equatorial coordinates to telescope hardware coordinates, execution of pre-defined standard routines for calibration processes that are called by a single entry in the command file, etc.) and sends commands to the hardware drivers.

Telescope Scheduler Input File

Also referred to as "scheduler request". Data file providing input to an observation scheduler. Opposed to telescope command files, these files usually do not contain absolute information on when a telescope shall perform a certain action, but rather constraints that allow a scheduler to flexibly allocate the requested actions. The scheduler, on the other hand, may write command files which are subsequently passed on to a telescope control computer.

Hardware Driver Input

Commands that are produced by a telescope control computer and are selectively sent to the according hardware drivers, e.g. the telescope mount drivers, dome drivers, etc.

1.3 Terms Related to the Proposed Format

Telescope Scheduling/Command Message (TSM)

Data file adhering to the proposed standard format. Can either serve as a telescope command file or as a telescope scheduler input file. Basically acts as a container for "Observation Blocks".

Observation Block

Smallest unit of an observation request/command. Are included in a Telescope Scheduling Message, with each Observation Block being represented by one XML element (with child elements). Observation blocks are treated as impartible and are the smallest unit to which the status "succeeded"/"not succeeded" can be assigned.

Command

Single observation block used to command an action from a telescope. Represented by an XML element called "`command`" (with child elements).

Schedule Request

Single observation block used to describe an observation request to a scheduler. Represented by an XML element called "`scheduleRequest`" (with child elements).

Segment

Higher-level XML element that contains child elements.

2 APPLICABLE AND REFERENCE DOCUMENTS

[RD1]	Review of Existing Formats for Telescope Commanding and Scheduling. SSA-NEO-ESA-TN-0011. Issue 1, Revision 1. 2014-03-24
[RD2]	CCSDS XML Specification for Navigation Data Messages. CCSDS 505.0-B-1. Issue 1. Blue Book. December 2010. http://public.ccsds.org/publications/archive/505x0b1.pdf
[RD3]	CCSDS Conjunction Data Message. CCSDS 508.0-B-1. Issue 1. Blue Book. June 2013. http://public.ccsds.org/publications/archive/508x0b1e1.pdf
[RD4]	CCSDS Orbit Data Messages. CCSDS 502.0-B-2. Issue 2. Blue Book. November 2009. http://public.ccsds.org/publications/archive/502x0b2c1.pdf
[RD5]	CCSDS Tracking Data Message. CCSDS 503.0-B-1. Issue 1. Blue Book. November 2007. http://public.ccsds.org/publications/archive/503x0b1c1.pdf
[RD6]	Space Debris System User Manual (Wide Field Camera). ESA contract N. 12166/96/D/IM. 1999. http://www.iac.es/telescopes/media/telescopios/OGS/documentos/sum.html
[RD7]	Monet and other Telescope Networks. Hessman, F. V., Dreizler, S., Beuermann, K.. Thinkship 3 Potsdam. 2004. http://www.cft.edu.pl/~lech/pi/Poczdam/MONET.ppt
[RD8]	Remote Telescope Markup Language (RTML). Hessman, F.V.. Astronomical Notes 327, 751-757. 2006.
[RD9]	Remote Telescope Markup Language 3.0g. 2004. http://www.astro.physik.uni-goettingen.de/~hessman/RTML/RTML-3.0g/
[RD10]	Minor Planet Center Format For Astrometric Observations Of Comets, Minor Planets and Natural Satellites, http://www.minorplanetcenter.net/iau/info/ObsFormat.html
[RD11]	ESO Phase 2 Preparation Proposal software. Version 3.4.0
[RD12]	ASCOM Initiative. http://ascom-standards.org/index.htm
[RD13]	ASCOM Platform Help. http://www.ascom-standards.org/Help/Platform/Index.html
[RD14]	XML Schema Part 2: Datatypes Second Edition. W3C Recommendation. 2004. http://www.w3.org/TR/xmlschema-2/
[RD15]	Definition of the Flexible Image Transport System (FITS). NASA/Science Office of Standards and Technology. NOST 100-2.0.. 1999. http://archive.stsci.edu/fits/fits_standard/
[RD16]	FITS keyword requirements. SSA-NEO-ESA-RS-003. Issue 1 Revision 6. 2014-08-01.
[RD17]	Optical Survey Detailed Description. Sánchez, N.. Memorandum. 2012.

Table 3: Reference Documents

3 INTRODUCTION

The vast majority of telescopes used for scientific purposes – both in professional and amateur communities – is operated using computer systems to steer the telescope pointing and control the instruments. The variety of telescope control software products and schedulers in use is hereby almost as large as the variety of existing telescopes. Even though some harmonization efforts have been undertaken over the last years, most software still requires a slightly different input format of data to command the telescope and instruments.

In effect, a researcher who authored an observation plan or a scheduler request for one telescope is in most cases not able to submit the document to another telescope without reformatting it first, even though the physical functionalities to be used are the same. Since many researchers and institutes frequently use different telescopes, they are regularly required to write observation plans and scheduler requests in different formats and to convert from one format to the other. In larger science campaigns where observations are simulated before they are conducted, yet another format of telescope command data is required as input for the simulation software.

To ease these processes and to reduce the efforts required from researchers that use several different telescopes and/or simulation software products, a standard data format for observation commanding and scheduling would be beneficial. As a first step, the different data formats currently in use by different institutions and commercial software packages were examined and compared [RD1]. Within this document, a potential standard format for telescope commanding and scheduling will be presented, referred to as “Telescope Scheduling/Command Messages” (TSM).

As such, the proposal in this document shall serve as a basis for discussions that finally shall lead to the widespread establishment of a standard.

4 BACKGROUND

[RD1] examined the different steps necessary on the typical path from an observation idea to the actual observation and the relevant types of data involved with those steps. It went on examining different formats that are used in each of those steps, namely

- The RTML standard providing an XML file format for observation time application, scheduler input (especially for remote telescope networks), and project documentation,
- The Observation Preparation Format of the European Southern Observatory (ESO), which is used for scheduler input to ESO's telescopes and makes use of parameter definition in ASCII files,
- The Short Term Plan (.stp) command files used to submit direct commands to the telescope control computer of the European Space Agency's (ESA) Optical Ground Station (OGS) in an ASCII format,
- The NEOPOP Observation Strategy Definition files (.osd) used as a telescope command file to simulate an observation using ESA's NEOPOP software,
- And the ASCOM standard architecture which provides a set of standard functions to be used for the communication between an observation control software (or a telescope control computer) and the actual physical devices (e.g. camera, telescope mount, filter wheel,…).

In addition this document takes into account recommended standards by the Consultative Committee for Space Data Systems which will be explained further in section 5 and the Remote Telescope System 2nd version (RTS2) package for remote telescope control including the Instrument-Neutral Distributed Interface (INDI) communication protocol.

Figure 1 gives a concise overview of where each format is located within the process chain, and which kind of data is required for each step.

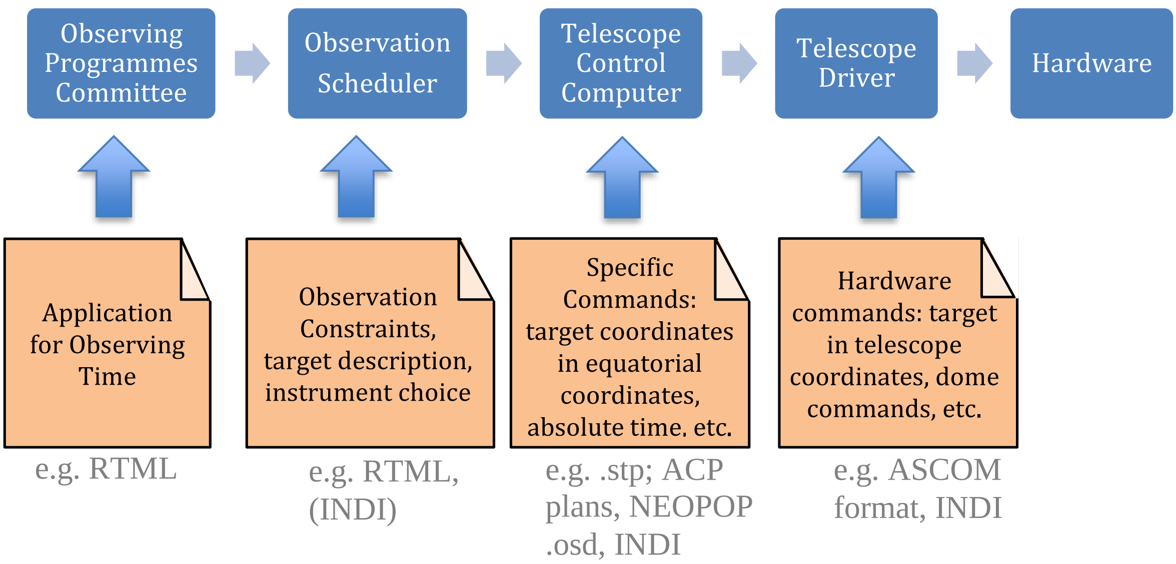

Figure 1 Process chain to an observation, required data, and corresponding formats

[RD1] then examined and compared mainly the parameters and commands available in each of the aforementioned formats in order to compile a list of commands and parameters in use at the different steps.
Based on the needs of potential users, the parameters and commands expected to be most commonly used were identified. Based on these and considerations concerning the general structure of the standard, the proposal in this document was designed.

5 SCOPE AND GENERAL NATURE OF THE STANDARD

5.1 Scope

For the scientific user, mostly telescope control computer inputs and local scheduler inputs are needed in terms of data types. Hardware commands (i.e. interfacing with the hardware drivers) as supported by the ASCOM standard are hardly necessary for scientific users who usually operate with observation software or scheduler frontends. Furthermore, solutions such as ASCOM already exist for this control level. For this reason, the standard will not include hardware commands.
Especially scientific users that use external telescopes of larger organisations (e.g. ESO, space based telescopes,…) also need to submit proposals for observation time. The required format for the proposals, however, differs between the organisations (e.g. ESO provides a LaTeX template, the Space Telescope Science Institute provides MS Word and LaTeX templates). While it would be desirable to also standardise the input for the proposal phase, it seems impracticable to establish one format for this phase among all major institutions. Furthermore, the more text-based content of proposals is less suitable for standardisation. Consequently, observation time applications are not included in the standard proposal, either. As figure 2 illustrates, thus only scheduler input and control computer input data are covered by the standard proposal, assuming that the telescope control computer or local scheduler will translate the transmitted data into a legacy or standardised hardware interface format that is used at each particular telescope.

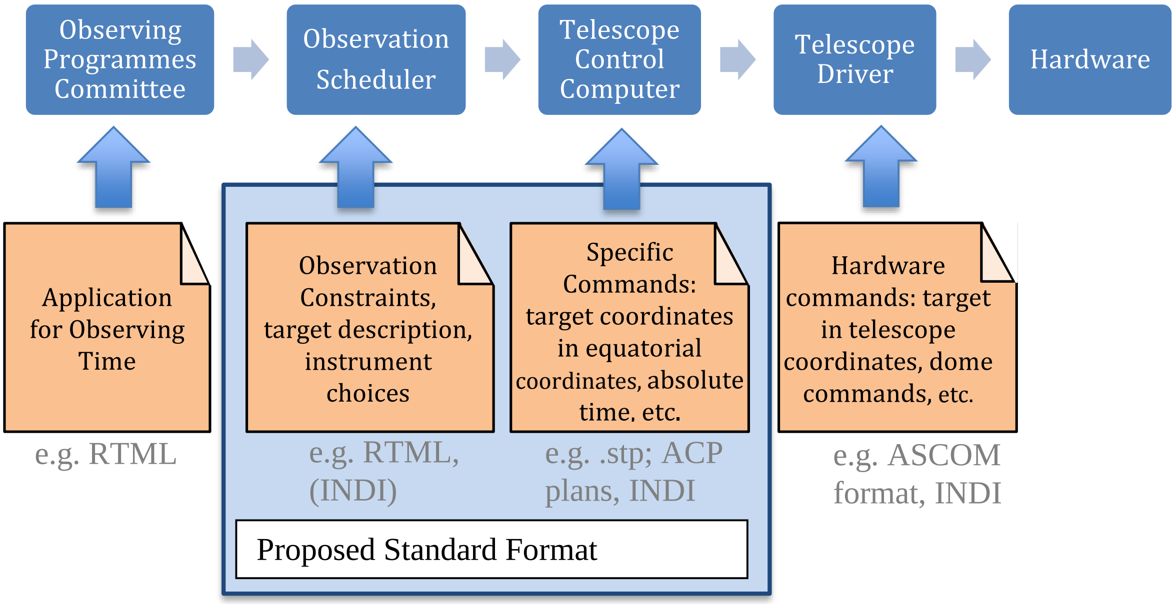

Figure 2 Data types included in the proposed standard

It should be mentioned that in theory, the INDI protocol as used in RTS2 could also be used to cover input to telescope control computers and part of the input to observation schedulers. It is in its nature focused on providing an interface to hardware, though, and less suitable for the representation of e.g. constraints or observation strategies.

5.2 Context of the Standard

The basic application scenarios of the standard are illustrated in figures 3 and 4, once for the application as a scheduler input file and once for the application as a telescope command file.
In the first case, the TSM file is created by a human operator or an automated planning tool and either directly submitted to an observation scheduler or retrieved by it from a database. The scheduler creates an observation schedule based on the targets and constraints provided in the TSM and sends corresponding commands to the telescope control computer. In case of a telescope network it is also possible that a central scheduler sends commands to several telescopes. The scheduler can be located at the telescope or work remotely. The scheduler needs to be reasonably “smart” to interpret the constraints in the TSM and to preferably calculate pointing coordinates from provided object ephemerides or retrieve information on objects from online sources.

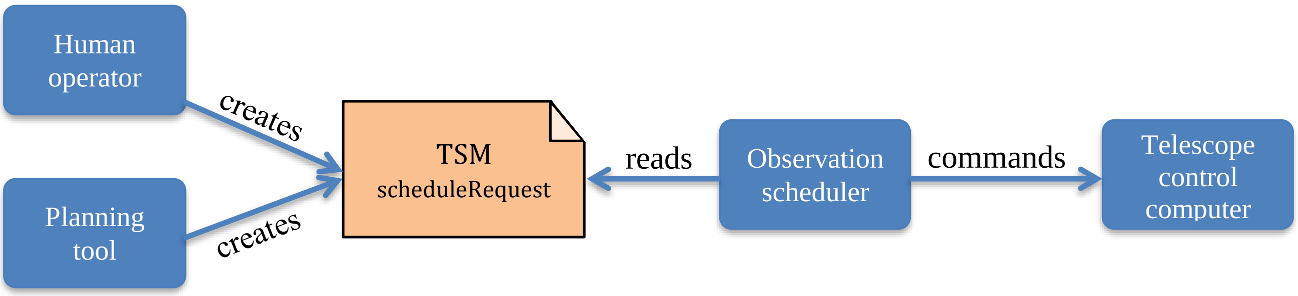

Figure 3: Basic context of TSM used as a scheduler input file

It is well possible that the observation scheduler passes on the command to the telescope control computer via another TSM, as illustrated in figure 4. The telescope control computer in this case is likely to be located somewhere close to the telescope. It needs to be much less “smart” than the scheduler, assuming that in the typical case it will already be provided by simple coordinates and timing information.

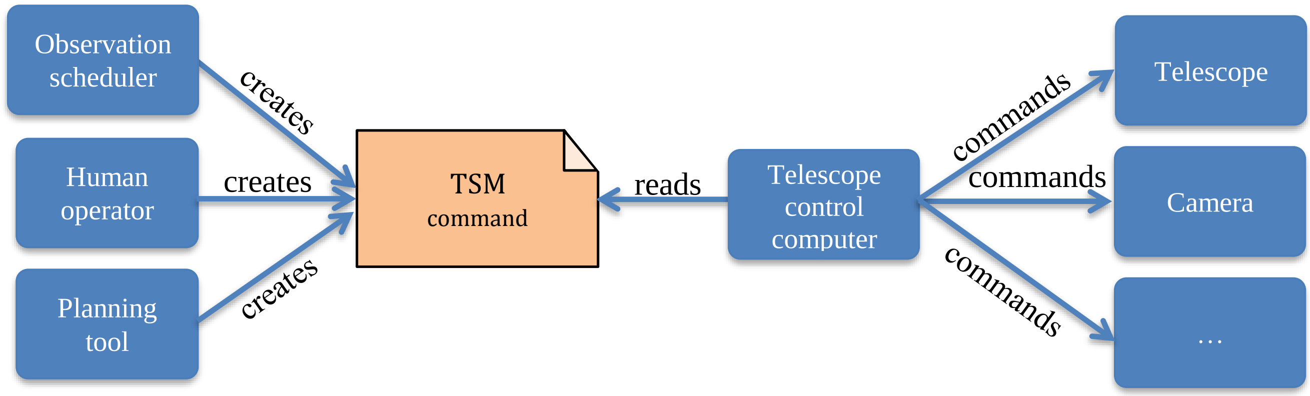

Figure 4: Basic context of TSM used as telescope command files

5.3 Documentation within the format

Another question to consider is how much documentation data the standard should support. For individual images, the FITS (Flexible Image Transport System) standard allows the inclusion of a considerable amount of information in the machine- and human-readable image header. There is thus no need to duplicate this information in a separate file for observations of several images. The same applies to information on used hardware in robotic telescope networks where observation requests are not submitted to individual telescopes. The information on the telescope eventually used can also be written to the images' FITS headers, as done in the Las Cumbres Observatory Global Telescope Network, for example. In case of larger campaigns, however, it might be useful to have access to a concise observation history in one file (i.e. which observations have really been carried out, actual observation conditions,…). For the sake of clearness, it would be preferable to have this information in a single file, not interrupted by command or other information. Such a format is thus not included in the proposed standard, but might be subject to future efforts.
To guarantee traceability from an image to the underlying command, however, the command message format foresees the option to request the command message ID (and potentially also its location) to be written into an image's FITS header.

5.4 Data format

There are several requirements for the data format used within the standard:

- Messages shall be human-readable
- Messages shall benefit from the advantages of modern programming
- Parsers and tools shall be available for the chosen format in as many programming languages as possible
- The format shall resemble established formats in the field if possible

Formats that generally qualify given the above requirements and are used for similar applications are plain ASCII notations (often in some sort of keyword-value notation), XML, or JSON.
Both XML and JSON offer the advantages of modern programming formats while still being human-readable. Since JSON came into vogue after XML, at the point of this writing there are still less parsers available than for XML. Additionally, XML has a developed concept of schemas. These can be used to define the general structure XML documents have to adhere to (i.e. the "grammar") and to automatically validate XML documents. XML thus would be the preferable format.
XML is also already in use by the RTML format as described in [RD1]. RTML, however, is much more encompassing than required for this standard (as described above) and very flexible. This offers many advantages, but makes the structure of command/request messages potentially complicated.
Other standards using XML are the ones recommended by the CCSDS on Navigation Data Messages (NDMs) [RD2] and Conjunction Data Messages (CDMs) [RD3]. While these are not used for the same purpose (telescope commands and schedule requests), they are frequently used in the field of space debris and satellite observations and operations and offer a very clear format that is well adaptable for telescope command / schedule request messages. CDMs can be written both in keyword-value notation and in XML, whereas the telescope/schedule request messages are only foreseen to be in XML.

In summary, the following decisions were taken on the general nature of the standard:

- The standard focuses on scheduler input & telescope control computer input.
- No focus on other project phases, e.g. detailed support for the application for observation time.
- There is no need to duplicate FITS header documentation within the command file format.
- The standard shall be a XML-based language in order to provide easy validation possibility of created command files.
- For this purpose, a grammar (“XML schema”) of the standard needs to be to created & made publically available.
- Since many data exchange formats in related fields (Orbit Data, Spacecraft Tracking Data, Spacecraft Conjunction Data) follow a common and clear format defined in several CCSDS recommended standards ([RD2], [RD3], [RD4], [RD5]), the standard shall also follow this format as closely as possible.

6 GENERAL FORMAT OF THE STANDARD

Due to the advantages of XML, the standard is proposed in an XML-based language. Telescope command and schedule request files will further be referred to as Telescope Scheduling/Command Messages (TSMs) in this document.
XML itself was developed to structure, transport and store data. It is thus not an executable language by itself, but rather provides a format for data exchange. Given this form, it is perfectly suitable for exchanging telescope command or scheduler input data that will be read by a scheduler or telescope control computer, which, on the other hand, then executes related commands.
As itself, XML is furthermore a meta-language and offers developers the possibility to define their own logically nested data containers, which is done for the proposed telescope command standard.

XML generally has the advantage of providing a logical, hierarchical structure to the documents and to the information contained within the documents. The logical layout of an XML document always follows a tree structure. This structure is very nicely visualized in an XML viewer, where a XML document can also be edited and generated. The other option would be to directly generate the XML document as an ASCII file. The layout of the XML commands in an ASCII file shall be explained later.

6.1 Minimal Example

For the impatient reader, a very minimal example shall follow, showing how a simple single observation can be commanded. Figure 5 shows the corresponding command file displayed in XML notepad, followed by the ASCII code notation of the file. A short explanation follows thereafter.
More detailed explanations, also including more parameters available in the standard, can be found in sections 6.2ff.

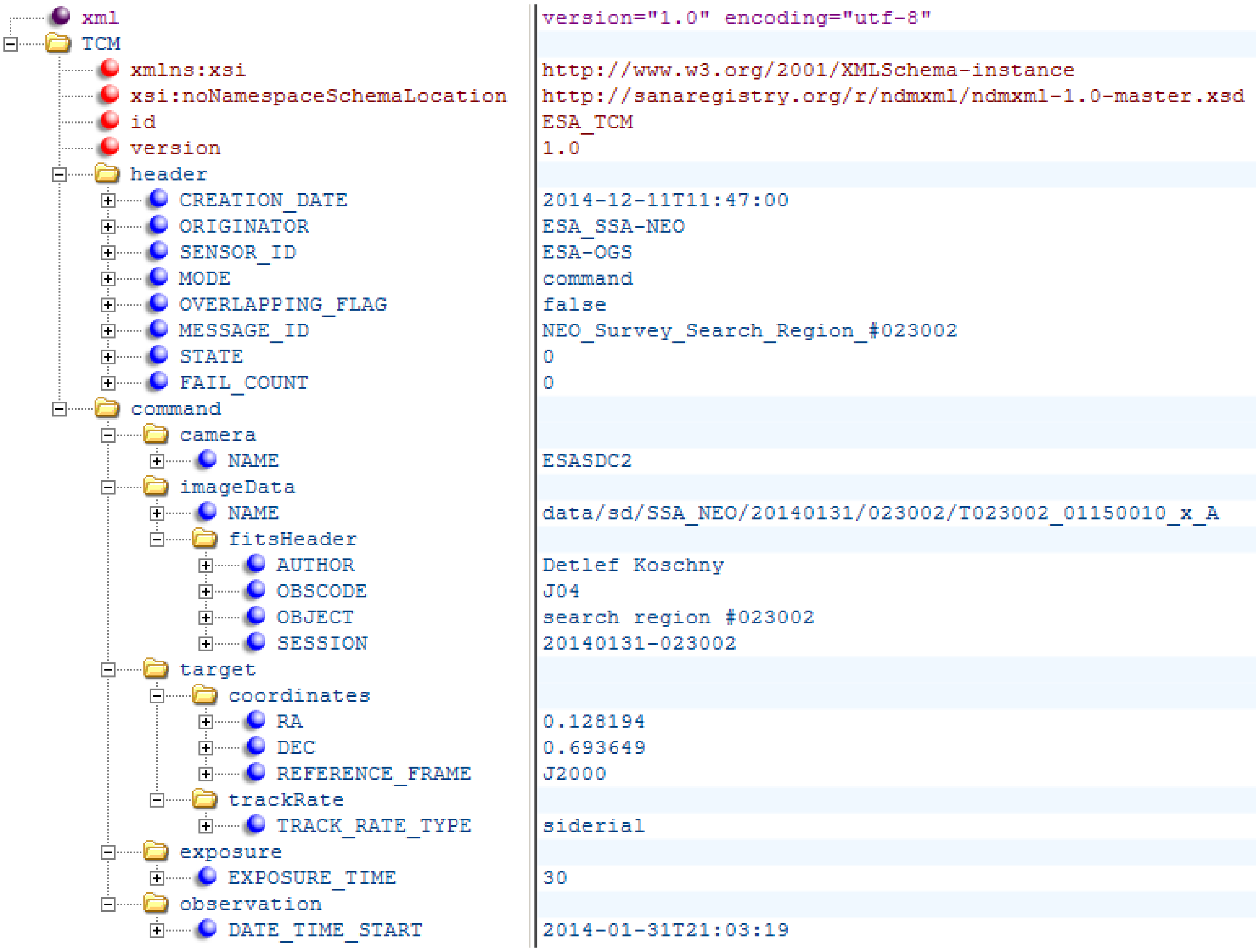

Figure 5 Minimal example of a command file for a single observation displayed in XML Notepad (the red lines are part of the XML header and may be ignored at this point)

```xml
<TSM xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-
    master.xsd" id="ESA_TSM " version="1.0">
    <header>
       <CREATION_DATE>2014-12-11T11:47:00</CREATION_DATE>
       <ORIGINATOR>ESA SSA-NEO</ORIGINATOR>
       <SENSOR_ID>ESA-OGS</SENSOR_ID>
       <MODE>command</MODE>
       <OVERLAPPING_FLAG>false</OVERLAPPING_FLAG>
       <MESSAGE_ID>NEO Survey Search Region #023002</MESSAGE_ID>
       <STATE>0</STATE>
       <FAIL_COUNT>0</FAIL_COUNT>
    </header>
    <command>
        <camera>
           <NAME>ESASDC2</NAME>
        </camera>
        <imageData>
           <DIRECTORY>data/sd/SSA_NEO/20140131/023002/</DIRECTORY>
           <NAME> T023002_01150010_x_A</NAME>
           <fitsHeader>
                   <AUTHOR>Detlef Koschny</AUTHOR>
                   <OBSCODE>J04</OBSCODE>
                   <OBJECT>search region #023002</OBJECT>
                   <SESSION>20140131-023002</SESSION>
           </fitsHeader>
        </imageData>
        <target>
           <coordinates>
                   <RA>0.128194</RA>
                   <DEC>0.693649</DEC>
                   <REFERENCE_FRAME>J2000</REFERENCE_FRAME>
           </coordinates>
           <trackRate>
                   <TRACK_RATE_TYPE>siderial</TRACK_RATE_TYPE>
           </trackRate>
        </target>
        <exposure>
           <EXPOSURE_TIME>30</EXPOSURE_TIME>
        </exposure>
        <observation>
           <DATE_TIME_START>2014-01-31T21:03:19</DATE_TIME_START>
        </observation>
    </command>
  </TSM>
```


Explanation

The “header” element contains basic parameters of the message itself. All actual commanding parameters for the telescope are, in the basic case, included in a “command” element. In this element, the camera to be used is specified, the path and filename where the resulting image file

shall be saved are detailed, information to be written into the image file's FITS header can be passed on, and the physical observation parameters are transferred. Hereby, coordinates are defined in decimal degrees, exposure time in seconds.
If more than one observation is desired, another "command" segment can be added at the end of the file. Overlapping information can, as explained later, be defined for all "commands" in a "commonData" segment.

6.2 Units Used

The following units are used in the standard proposal:

- deg: decimal degrees
- as: arcsecond (1/3600 degree)
- m: meter
- mm: millimeter
- nm: nanometer
- s: SI seconds
- min: minutes (60 SI seconds)
- us: microseconds (10^-6 SI seconds)

In order to simplify the standard and the interface to a telescope control computer or scheduler, only one notation per parameter is foreseen.

6.3 Parameter Types

The parameter types used in this standard proposal follow the W3C Recommendation 28 that defines data types in XML [RD14]. They are broadly outlined in the following. For a detailed definition, however, the W3C Recommendation shall be consulted.

- **double:** double precision floating point number format as per reference [RD14]. A period is used as a decimal indicator. An optional leading sign is allowed. If the sign is omitted, "+" is assumed. Leading and trailing zeroes are optional. Additional limitations may apply for specific elements.
- **boolean:** may have the values "true", "false", "0", or "1"
- **string:** represents character strings.
- **dateTime:** represents a time and date in the format YYYY-MM-DD**T**HH:MM:SS.SSS (in line with ISO 8601 and xsd dateTime datatype). More than three digits are allowed for fractional seconds, however, no trailing zeros are allowed. "T" serves as a separator indicating that time-of-day follows. All dateTimes must be provided in UTC.
- **duration:** represents a time duration in the format "**P**n**Y**n**M**n**DT**n**H**n**M**n**S**" (in line with ISO 8601 and xsd duration datatype). "P" is mandatory and indicates that a time period is stated. "T" serves as a separator between the date and the time section, it is mandatory if hours, minutes, or seconds are specified. "n" is an integer stating the duration (fractional seconds are allowed). The unit is indicated by the following letter, i.e. "Y" for years, "M" for

months, "D" for days, "H" for hours, "M" for minutes, "S" for seconds. Time duration specifications might thus be as follows:
  - o P5Y – 5 years
  - o PT60S – 60 seconds
  - o PT600S – 600 seconds
  - o PT3M30S – 3 minutes, 30 seconds
  - o P1M5DT10H – 1 month, 5 days, 10 hours
  - o –PT10M – negative 10 minutes.
- **int:** integer number with up to 18 digits as per reference [RD14]. Additional limitations may apply for specific elements.

6.4 Nested logical segments in the format

The format uses nested XML elements, with the elements holding child elements being referred to as "logical segments". In the following description, not the entire hierarchical structure is displayed graphically. Instead, elements are listed in tables with

a. Logical segments of second level elements being indicated by an empty line before and after the segment, and the segment being introduced with its name;
b. Logical segments within second or lower level elements being indicated by being indented. In this case, all elements listed after the segment title are part of this particular segment until either a new segment starts (indicated by a segment name on the same level) or the indent moves back to the higher level.

Lower-level elements that are marked as mandatory but located within a logical segment that is not mandatory are only mandatory if the optional, higher-level logical segment is used.

6.5 General rules

Delay times

Delay times defined in this standard proposal shall be interpreted as minimum delay times. I.e. if a delay time of 30 s is foreseen between two exposures, and the readout of the first exposure takes 20 s, the next exposure shall still start 30 s after the end of the first exposure time (and 10 s after the readout of the first exposure was completed). Obtaining observations at the correct time requires the requesting observer to know and take into account system-internal delay times such as readout times.

Examples:

A delay time of 30 s is specified, the readout of the first exposure takes 20 s. – the next exposure starts 30 s after the end of the first exposure time.

A delay time of 0 s is specified, the readout of the first exposure takes 20 s. – the next exposure starts 20 s after the end of the first exposure time.

A delay time of 20 s is specified in between two commands, but the DATE_TIME_START of the second command is 10 s after the end of the first exposure time and TIME_START_TOLERANCE (see next segment) is not defined – the second command is not carried out, the entire TSM file is marked as not successful.

If a negative delay time is provided that would require a tracking movement to be initiated before the end of the preceding exposure/delay time, the later command shall not be carried out.

Unforeseen/unknown delays in direct commanding ("command" segments)
In the default case of using direct telescope control ("command" segments), a specific observation time is requested. Consequently, if the observation cannot be carried out at the exact requested time, due to e.g. internal delays or weather, the observation should be skipped and marked as not successful. If this should be avoided and the functionality is supported by the corresponding telescope, however, an allowable non-zero delay time for observation starts can be specified via the "TIME_START_TOLERANCE" element of the observation segment in commonData. If no TOLERANCE element is provided (applies also for the waitConstraint segment), the default should be a tolerance of one second. Tolerances for start, end or wait times may be defined for an entire TSM message in the commonData segment.

Check of validity
A TSM file should be checked for its validity by checking it against a TSM XML schema either by the submitting entity, the receiving entity, or both. In this manner, the adherence to the grammar and the correctness of used data types can be ensured before submission or execution.
Different levels of validity checks are possible:

1. A TSM file can be checked against the general TSM XML schema to be provided by ESA or another international entity. This provides a general check whether the file is compliant with the standard, but does not take into account whether the specific observatory the file will be submitted to supports the provided information and whether values are within the range supported at the observatory. It is thus highly recommended to perform validity checks against XML schemas provided by the observatory the TSM file should be submitted to, if available.
2. A TSM file can be checked against a TSM XML schema provided by individual observatories, either for the observatory in general or for specific instruments or types of observations. This provides the opportunity to ensure that all explicitly or implicitly requested services are available at the observatory and that all values are within the allowed range. Observatories are strongly encouraged to provide XML schemas based on the general TSM XML schema for individual instruments and/or types of observations, or at least for the observatory in general.

Default behaviour in case of erroneous input
Default behaviour of observatory/scheduler systems in case of grammatically valid, but otherwise illogical, contradictory, or impossible input is indicated for many elements in italic font within the element description.
Generally, if erroneous input is detected or referenced resources (e.g. a camera name) cannot be identified, a warning message shall be delivered to the requester via the agreed notification system.
Where NAME keywords are not mandatory, observations shall still be conducted if a NAME keyword is present, but the referenced resource cannot be identified.
In case resources referenced in all other non-mandatory elements cannot be identified, values are out of range or cannot be specified for the specific instrument, the requested observation should still be carried out with a warning message being delivered to the requester if not otherwise specified in

the element description. If a numeric value is not applicable, the closest applicable value on a logarithmic scale should be used (“scaled rounding”, the input value is rounded to the applicable value whose log is closest to the log of the input value). Observatories may decide to agree on other procedures.
In case of either/or available element sets (e.g. coordinates or ephemerides in “target”), the element mentioned first in the “Mandatory” column description shall have priority.

Significance of element order
Elements in TSMs are required to appear in the order as documented in this standard.

Exchange of TSM files
The method of exchanging TSMs shall be decided by the participating parties.

Time specification
All time-tags in the TSM shall be in UTC.

Leading and trailing empty spaces in XML elements
Leading and trailing empty spaces in XML elements are not significant.

Case Sensitivity
Higher level XML elements that may contain child elements are noted in lowerCamelCase. I.e. the first character of a character string formed from concatenated words is lowercase, and the initial character of subsequent concatenated words is capitalized, as in lowerCamelCase. In the case of a character string consisting of only a single word, only lowercase characters are used.
Lowest-level XML elements that may only contain a value, but no child elements are noted in capital letters.
Values supplied to lowest-level elements shall not be treated as case sensitive.

Commenting
Creators of a TSM (PIs, …) are encouraged to use comments within any higher level XML elements to add informative data. They are also encouraged to use comments directly after lowest-level XML elements to provide further information on the preceding element. The syntax for writing comments is the following:
<!-- This is a comment -->

6.6 Telescope Control Computer and Telescope Scheduler Inputs

In order to account for the different nature of telescope control computers and schedulers, TSMs should be created in one of two different modes, tailored to each application. Telescope control computers are thereby assumed to apply relatively little processing to a submitted command and to merely process them in chronological order (compare the Level 1 Controller of the ESA OGS and .stp files). Telescope schedulers, on the other hand, are assumed to be capable of much more complex processing, including the processing of constraints, loops, or links between submitted blocks.
Following this distinction, TSMs submitted to a telescope control computer as described above may (in addition to header, metadata, and commonData) only include “command” elements and must be

marked as “command” in the TSM header’s MODE element. The resulting TSM is also referred to as “Telescope Command File”.
TSMs submitted to a scheduler, on the other hand, may also contain scheduleRequest elements or more complex first level elements (see section 10.3) and must be marked as “request” in the TSM header’s MODE element. The resulting TSM is also referred to as “Telescope Scheduler Input File”.

6.7 Quantization of Commands/Requests

Having well defined smallest units of observations is very helpful for schedulers, but also makes a format more intuitive. In a TSM, the smallest unit of an observation request/command is one “command” or “scheduleRequest” element. One smallest unit is also referred to as a “block”. Effectively, this means that schedulers would extract all the blocks from one TSM file upon receiving it and generally treat them as separate entities. Blocks should furthermore be treated as impartible and be the smallest unit to which the status “succeeded”/”not succeeded” can be assigned. TSM allows the handling of blocks by allowing the specification of unique IDs for each command/scheduleRequest element, and by providing “STATE” and “FAIL_COUNT” elements for each command/scheduleRequest. Blocks furthermore can be referred to each other, e.g. in form of constraints, their success can be linked, and they can also be used in higher-level logic, e.g. as part of sequences (see section 10.3).
A TSM file basically acts as a container for blocks, e.g. for all blocks that get submitted for one night by an observer (see also figure 6). TSM files themselves also have unique IDs, they also offer STATE elements to indicate their status, and they also can be linked to other TSM files. Their STATE may well be expressed as a decimal value depending on the current status of the blocks contained within it.

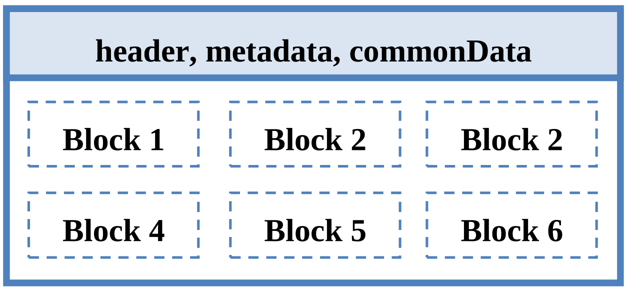

Figure 6: : General architecture of a telescope scheduling message

7 DETAILED TSM SYNTAX

7.1 Introduction: First-Level Structure

A Telescope Scheduling/Command Message (TSM) shall consist of a combination of the following first-level elements:

a) a header (containing basic parameters of the message);
b) metadata (containing information on the creator of the message and linked messages);
c) common data (containing common parameters for all following commands or schedule requests);
d) command (a command for a particular observation. Typically a TSM will contain several. Since a command contains absolute times for actions, it is assumed that user has prior knowledge about slew times etc. and considered those when choosing times);
e) schedule request (a request to schedule a particular observation. Typically a TSM will contain several).

A TSM must contain at least a header and at least one command or schedule request. Both metadata and common data are optional. Typically, a TSM will contain either commands or schedule requests.

Figure 7 shows these first level elements in an XML viewer.

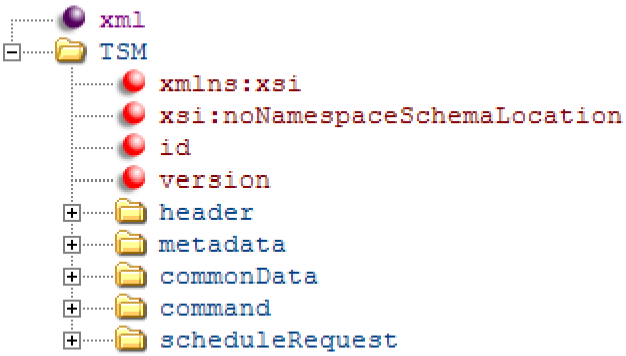

Figure 7 Available standard first level elements of a TSM document (red lines are part of the XML header and can be ignored at this point. They are further explained in section 10.1)

7.2 Definition of the segment ‘header’

The TSM header shall contain the elements as shown in figure 8. The TSM header is mandatory.

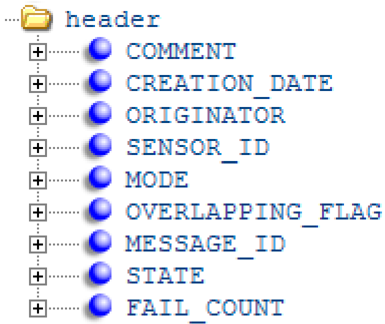

Figure 8: Available elements of a TSM header

Keyword	Type	Description	Mandatory
COMMENT	string		No
CREATION_ DATE	dateTi me	Message creation date/time in Coordinated Universal Time (UTC).	Yes
ORIGINATO R	string	Creating agency of the message.	Yes
SENSOR_ID	string	ID that uniquely identifies the sensor (telescope/observatory/network, potentially also main instrument) subject of the observation request. The format and content of the sensor identifier value are at the discretion of the originator.	Yes
MODE	string	Indicates whether the TSM is used as a direct input file for a telescope control computer (i.e. only contains chronologically executable “command” segments) or as an input for a more complex scheduler (i.e. also contains “scheduleRequest” segments or other segments with more complex logic). Allowed values are “command” and “request”	Yes
OVERLAPPI NG FLAG	boolean	Flag to indicate whether an overlapping with a pre-existing plan exists	Yes
MESSAGE_I D	string	ID that uniquely identifies a message from a given originator. The format and content of the message identifier value are at the discretion of the originator.	Yes
STATE	string	State of the observation. “1” indicates that the observation has been successfully completed, “0” that it has not been successfully completed. Mostly useful for robotic telescope networks. Other STATE values can be used for internal processing	Yes

		of telescope networks. *Systems might also use decimal values that indicate that a certain amount of the blocks (commands/scheduleRequests) within a TSM are already completed. Non-zero values that do not begin with "1" that are unknown/unsupported by a receiving system shall be treated like "0".*	
FAIL_COUNT	integer	Number of failed attempts to execute the requested observation. Mostly useful for robotic telescope. Value might thus usually remain at "0" for non-network telescopes	Yes

7.3 Definition of the segment 'metadata'

The TSM metadata shall consist of the elements and sub-elements shown in figure 9. The TSM metadata is not mandatory.

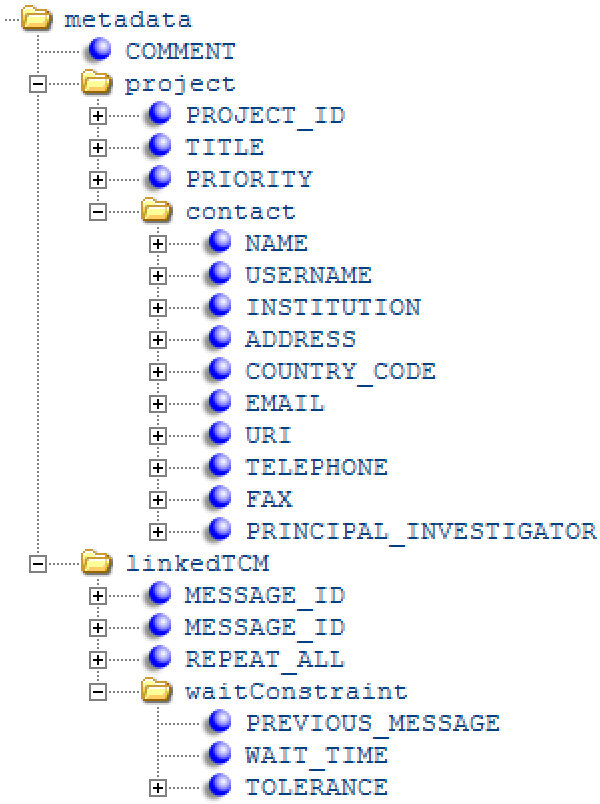

Figure 9: Available elements in TSM metadata

Keyword	Type	Description	Mandatory
COMMENT	string		No
project segment			No
PROJECT_ID	string	Project name / identifier.	No
TITLE	string	Project Title.	No
PRIORITY	double	Relative priority of the project. No specific scale is predetermined, thus valid scales of the targeted telescope/organisation can be used.	No
contact segment			No
NAME	string	Name of the entity / person making the request / command.	No

USERNAME	string	Possible username of the contact person/entity. Mainly interesting for at least partly automated systems where observers obtain unique usernames.	No
INSTITUTION	string	Name of the institution the requesting agent belongs to. Several INSTITUTION elements may be included.	No
ADDRESS	string	Address of the contact entity.	No
COUNTRY_CODE	string	Country code of the contact entity (preferably according to ISO 3166).	No
EMAIL	string	Email address of contact entity. Several EMAIL elements may be included.	No
URI	string	Uniform resource identifier of the contact entity.	No
TELEPHONE	string	Telephone number of the contact entity. Several TELEPHONE elements may be included.	No
FAX	string	Fax number of the contact entity. Several FAX elements may be included.	No
PRINCIPAL_INVESTIGATOR	boolean	Indicates whether this contact entity (in case several are listed) is the project's principal investigator.	No
linkedTSM segment		Allows message to be linked (and thus executed together) with other separate TSM files. Also allows definition of wait times between messages via the waitConstraint segment.	No
MESSAGE_ID	string	Message ID of linked TSM file. linkedTSM segment may contain several MESSAGE_ID elements. *If no TSM file with the stated MESSAGE_ID exists, and REPEAT_ALL is false, the missing message should be ignored. In the same case, if REPEAT_ALL is true, the current observation and all other linked messages should be marked and treated as unsuccessful.*	No
REPEAT_ALL	boolean	Indicates whether in case the observation of one of the linked TSM fails, all linked TSMs shall be executed again/whether the success of one message depends on the success of all other linked messages. If not listed, default state is "false".	No
waitConstraint segment		Allows to specify a specific wait time after the end of execution of the linked TSM. For details and sub-elements see page 49.	No

7.4 Definition of the segment 'commonData'

The TSM commonData segment is not mandatory. It is merely used to avoid the repeated listing of keywords that are the same for several "command" and/or "scheduleRequest" segments within one TSM. Once keywords that are mandatory in "command" or "scheduleRequest" segments have been defined in the "commonData" segment, they are not mandatory in following "command" and "scheduleRequest" segments anymore. If an element is defined in commonData, but also in one of the subsequent command or scheduleRequest segments, the value in the individual command or scheduleRequest segment shall be used for that particular command or scheduleRequest, without affecting following commands or scheduleRequests. This should also hold true for elements of which multiple instances are allowed within one command or scheduleRequest segment, such as the dateTimeConstraint or the nightConstraint.
The TSM commonData segment may consist of the elements / segments shown in figure 10.

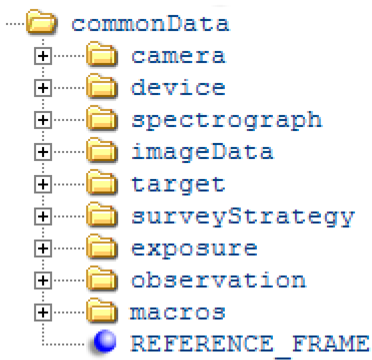

Figure 10: Available elements in TSM commonData

Keyword	Type	Description	Mandatory
camera segment		*See detailed description in section 7.5*	No
device segment		*See detailed description in section 7.5*	No
spectrograph segment		*See detailed description in section 7.5*	No
imageData segment		*See detailed description in section 7.5*	No
target segment		*See detailed description in section 7.5*	No
surveyStrategy segment		*See detailed description in section 7.6*	No
exposure segment		*See detailed description in section 7.5*	No
observation segment		*See detailed description in section 7.5*	No
macros segment		Holds segments that can be used in following elements of the TSM	No
REFERENCE_FRAME	string	Can be used to provide a global reference frame in which all coordinates provided in the TSM file are	No

		defined. Is overwritten by REFERENCE_FRAME elements in lower level elements. Allowed values at the moment are “J2000”, “ICRF”, “horizontal”. Default is “J2000”.	
ORIGIN	String	Origin of the equatorial coordinate systems. Either “topocentric” or “geocentric”. Default is “topocentric”.	No

7.5 Definition of the segment ‘command’

A TSM will usually contain several “command” segments, each holding information on one particular observation. One observation can, however, consist of multiple exposures of the same target, which for example can be commanded within one “command” segment by using several “observation” sub-elements.
The TSM command segment is not mandatory, but at least one TSM command or TSM scheduleRequest segment must be contained in a TSM.
Figure 7 shows the available second-level elements in a TSM command. Each element and its sub-segments are explained in further detail thereafter.

Figure 11: Available 2nd level elements in a TSM command

7.5.1 blockMetadata segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
BLOCK_ID	string	Unique ID of the command.		No
STATE	string	State of the command. “1” indicates that the observation has been successfully completed, “0” that is has not been successfully completed.		No
FAIL_COUNT	string	Number of failed attempts to execute the requested observation. Mostly useful for robotic telescopes.		No

7.5.2 *camera segment*

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
NAME	String	Name of the camera to be used.		No
detector segment				No
NAME	String	Name of the detector to be used if more than one is available for the requested camera.		No
chips segment		If a camera with multiple chips is used, the chips to be used can be specified with their ID numbers in this element. If the element is not included or empty, all chips of the detector are used. It is recommended to include a link to an explanation of the detector layout in a comment element.		No
chip segment		Segment referring to one specific chip. Chip ID must be added as an attribute, e.g. defining <chipID=”1”/>. May or may not have the child element “windowing”.		Yes
windowing segment		Allows the user to acquire windowed images on the parent chip. For sub-elements see below.[1]		No
binning segment				
X_ FACTOR	double	Binning factor to be used in x-direction.	-	No
Y_ FACTOR	double	Binning factor to be used in y-direction.	-	No
FLUSH_RATIO	integer	Number of lines shifted at once during flushing.	-	No
READOUT_ SPEED	double	Offers the possibility of determining the readout speed if the instrument permits this. Possible readout speeds need to be retrieved for each individual instrument.	us/pixel	No
SENSITIVITY	double	Offers option to set the sensitivity/gain to be used if the detector permits it. Available options need to be retrieved	-	No

[1] For .stp file users: TSM does not foresee a separate element for active area offset, as available via the “xorigin” and “yorigin” parameters of “setgeneral” in an stp. This functionality would have to be controlled via the windowing element.

		for each individual detector.		
windowing segment		Allows the user to acquire windowed images. Applies to all chips if defined outside a "chip"element.[1]		No
lowerLeft segment				
X	integer	x-coordinate in pixels.	-	No
Y	integer	y-coordinate in pixels.	-	No
upperRight segment				
X	integer	x-coordinate in pixels.	-	No
Y	integer	y-coordinate in pixels.	-	No
POSITION_ ANGLE	double	Position angle of the detector if it is rotatable inside its setup.	deg	No
filterWheel segment		Container for filters that should be used for the observation.		No
filter segment				
NAME	string	Name of filter to be used. Can be a URI *If requested NAME is not available at the telescope, but a FILTER_TYPE is specified, a filter of this FILTER_TYPE that is available at the telescope shall be used if possible)*		No
FILTER_ TYPE	string	Type of filter requested (if not a specific one is required). Allows the following entries: "clear, U, B, V, R, I, Z, Y, J, H, K, L, M, N, Q, VR, w, RI, *wavelength*". Where *wavelength* is the integer centre wavelength of a narrowband filter.[2] *If contradictory to the filter referenced to by NAME, NAME shall have priority.*		No
shutter segment		Optional segment that allows the user to choose among different shutters (if available) and to choose a shutter mode, if this is offered by the specific telescope in question. Further settings might be communicated in an "AUXILIARY_MESSAGE" element[3]		No
NAME	string	Name of the shutter to be used if more		No

[2] See section 10.6 for more details on the expected behavior regarding filters.
[3] See section 10.2 for more details.

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		than one is available for the requested camera.		
MODE	string	If offered by the particular telescope, a shutter mode pre-defined by the telescope may be chosen via its name in this parameter.		No
POINTING_ OFFSET	integer	Contains the chip number to the centre of which all target pointing should refer in case of a camera with multiple chips. If the element is not included or empty, pointing refers to the centre of the mosaic of chips.	-	No

7.5.3 device segment

(not mandatory)

Keyword	Type	Description	Mandatory
NAME	string	Name of the device to be used.	No
device segment		potential sub-device used in the parent device	No
DEVICE_TYPE	string	Specifies requested device type	No
SPECTRAL_ REGION	string	Describes in which spectral region the requested device shall work.	No

7.5.4 spectrograph segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
NAME	string	Name of the spectrograph to be used.		No
detector segment		see detailed description in “camera” segment		No
device segment		see detailed description in “device” segment		No
grating segment				No
NAME	string	Name of the grating to be used.		No
ORDER	non-	Number of orders that may be used (others		No

	negative integer	need to be filtered if possible)		
filterWheel segment		see detailed description in “camera” segment		No
POSITION_ ANGLE	double	Position angle of the detector if it is rotatable inside its setup.	deg	No
slit segment				
NAME	string	Name of the slit or slitmask to be used.		No
xyPosition segment				No
X	integer	x-coordinateof slit/mask centre in pixels.	-	No
Y	integer	y-coordinate of slit/mask centre in pixels.	-	No
coordinates segment		Alternative segment to xyPosition segment. Coordinates must be compatible with coordinates provided in the accompanying target element.		No
RA	double	Right ascension of requested slit centre position	deg	No
DEC	double	Declination of requested slit centre position	deg	No
AZ	double	Azimuth of requested slit centre position (either RA & DEC or AZ & EL allowed)	deg	No
EL	double	Elevation of requested slit centre position (either RA & DEC or AZ & EL allowed)	deg	No
REFERE NCE_ FRAME	double	Reference frame of the provided coordinates. Allowed values at the moment are “J2000”, “ICRF”, “horizontal”. Default is “J2000”.	-	No
ORIGIN	String	Origin of the equatorial coordinate system. Either “topocentric” or “geocentric”. Default is “topocentric”.	-	No
POSITION_ ANGLE	double	Position angle of the slit if it is rotatable inside its setup.	deg	No
shutter segment		Optional segment that allows the user to choose among different shutters (if available) and to choose a shutter mode, if this is offered by the specific telescope in question. Further settings might be communicated in an “AUXILIARY_MESSAGE” element		No
NAME	string	Name of the shutter to be used if more than one is available for the requested spectrograph.		No
MODE	string	If offered by the particular telescope, a shutter mode pre-defined by the telescope		No

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		may be chosen via its name in this parameter.		
SPECTRAL_ REGION	string	Describes spectral region in which the requested spectrograph shall operate.		No
POINTING_ OFFSET	integer	Contains the chip number to the centre of which all target pointing should refer in case of a camera with multiple chips. If the element is not included or empty, pointing refers to the centre of the mosaic of chips.	-	No

imageData segment (not mandatory)

Keyword	Type	Description	Mandatory
DIRECTOR Y	string	If allowed by the observing software/server, path of the image file to be created. *If not allowed, or if an invalid directory name is provided, images should be saved to the default directory.*	No
NAME	string	Name of the image file to be created.	Yes
fitsHeader segment		Contains keywords and their values that shall be written into the FITS header, if images are saved in FITS format. Element names are equivalent to FITS header keyword names that shall be written. It is assumed that the keywords required by the FITS standard are automatically written. Keywords can be overwritten by telescope systems.	No
COMPRESSI ON_TYPE	string	Offers option to choose the compression type in which the image data shall be delivered (if supported by the observing institution)	No
DELIVERY_ TYPE	string	Offers option to choose how the data files shall be delivered (if supported by the observing institution)	No

7.5.5 target segment

(not mandatory)

Keyword	Type	Description	Mandatory
NAME	string	Name of the target	coordinates or ephemerides or NAME
TARGET_T YPE	string	Indicates the type of target to be observed, e.g. SST or NEO	No

coordinates segment				coordinates or ephemerides or NAME
RA	double	Right ascension of the target	deg	Either RA&DEC or AZ&EL
DEC	double	Declination of the target	deg	Either RA&DEC or AZ&EL
AZ	double	Azimuth of the target (either RA & DEC or AZ & EL allowed)	deg	Either RA&DEC or AZ&EL
EL	double	Elevation of the target (either RA & DEC or AZ & EL allowed)	deg	Either RA&DEC or AZ&EL
REFERENCE_FRAME	double	Reference frame of the provided coordinates. Allowed values at the moment are “J2000”, “ICRF”, “horizontal”. Default is “J2000”.	-	No
ORIGIN	String	Origin of the equatorial coordinate systems. Either “topocentric” or “geocentric”. Default is “topocentric”.	-	No
ephemerides segment				coordinates or ephemerides or NAME
EPHEMERIDES_TYPE	string	Indicates in which format ephemerides are provided. Available options are: SSA ID; International Designator; OEM[4]; OPM[5]; TLE, MPC Format. If any of these are chosen, the user must ensure that the telescope supplies a suitable orbit propagator or look-up tool to retrieve the target coordinates at the observation epoch. SSA ID, International Designator, and MPC Format[6] must be provided in a following EPHEMERIDES_DATA element. All others are expected in an additional file referenced in a following URI element.		raDecList , or EPHEMERIDES_TYPE, or orbitalElements
EPHEMERIDES_DATA	string	Object ephemerides either expressed as SSA ID, International Designator, or in MPC Format		Mandatory if EPHEMERIDES_TYPE is SSA ID, International

[4] Orbit Ephemerides Message, as defined in [RD4].
[5] Orbit Parameter Message, as defined in [RD4]. Specifies position and velocity vectors of an object at one certain epoch.
[6] Minor Planet Center export format for Minor-Planet Orbits as detailed at http://www.minorplanetcenter.net/iau/info/MPOrbitFormat.html. It is sufficient if the telescope control computer / scheduler reads in the first 103 characters (not counting leading spaces) of EPHEMERIDES_DATA provided in MPC format.

				Designator, or MPC Format
orbitalElements segment				raDecList , or EPHEMERIDES_TYPE, or orbitalElements
OBJ_ EPOCH	dateTime	Epoch at which the object position is provided (in UTC)	-	Yes
ORBIT_ CENTER	string	Center of coordinate system in which keplerian orbital elements are provided. Options are “Sun” and “Earth”		Yes
MEAN_ ANOMALY	double	Mean anomaly of the object at the specified epoch	deg	Partly
ARGUMENT_ PERICENTER	double	Argument of pericenter at J2000.0	deg	Partly
LAN	double	Longitude of the ascending node at J2000.0	deg	Partly
INCLINATION	double	Orbit inclination (to the ecliptic in case of heliocentric elements, to the equator in case of geocentric elementes) at J2000.0	deg	Yes
ECCENTRICITY	double	Orbital eccentricity	-	Yes
SMA	double	Semimajor axis	km	Yes
ARGUMENT_ LATITUDE	double	Argument of latitude, to be used instead of ARGUMENT_PERICENTER and MEAN_ANOMALY in case of a circular orbit	deg	Partly
LONGITUDE_ PERIGEE	double	Longitude of perigee, to be used instead of the LAN and ARGUMENT_PERICENTER in case of an equatorial/ecliptic orbit	deg	Partly
TRUE_LONGTIUDE	double	True longitude, to be used instead of LAN, ARGUMENT_PERICENTER, and MEAN_ANOMALY in case of a circular and equatorial/ecliptic orbit	deg	Partly
raDecList segment		Allows user to provide tracking information in form of RA-DEC-time sets. The user must ensure that the telescope/observatory supports this form of tracking. Coordinates of consecutive waypoints shall be listed in their temporal order, e.g. RA, RA, RA, DEC, DEC, DEC, DATE_TIME, DATE_TIME, DATE_TIME. Coordinates and times shall be connected according to their order of appearance, i.e. the first listed RA element belongs to the first listed DEC element and the first listed DATE_TIME element.		raDecList , or EPHEMERIDES_TYPE, or orbitalElements

RA	double	Right ascension	deg	Yes
DEC	doube	Declination	deg	Yes
DATE_TIME	dateTime	Time at which the telescope shall pass the corresponding RA-DEC pair.		Yes
REFERENCE_FRAME	double	Reference frame of the provided coordinates. Allowed values at the moment are "J2000", "ICRF". Default is "J2000".	-	No
ORIGIN	String	Origin of the equatorial coordinate system. Either "topocentric" or "geocentric". Default is "topocentric".	-	No
URI	string	URI at which ephemerides are available		If required by chosen EPHEMERIDES_TYPE, e.g. OEM, OPM, TLE
targetBrightness segment		Optional element to provide the target's expected brightness in apparent magnitudes, in case the observation parameters shall be chosen automatically		No
MAGNITUDE	double	Target brightness in terms of apparent magnitude when using the subsequently defined filter type.	-	No
BAND	string	Standard band for which the previously stated target magnitude applies. Must be a band that the individual telescope's exposure time calculator accepts. Case sensitive.	-	No
MAG_SYSTEM	string	System in which the magnitude is defined. Allowed values are "Vega" for the Johnson System and "AB" for the AB System. Default is the AB system.	-	No
trackRate segment				Yes
TRACK_RATE_TYPE	string	List of standard track types: none, stationary, sidereal, ephemerides. "Ephemerides" need to be selected if target ephemerides shall be tracked during an exposure (only stating target in ephemerides is not sufficient).	-	Yes
RA_OFFSET_RATE	double	Offers option to specify tracking with an offset rate to any of the TRACK_RATE_TYPEs. The track type to which the offset shall apply must be specified in TRACK_RATE_TYPE.	as/s	No
DEC_OFFSET_RATE	double	Offers option to specify tracking with an offset rate to any of the	as/s	No

		TRACK_RATE_TYPEs. The track type to which the offset shall apply must be specified in TRACK_RATE_TYPE.		
AZ_OFFSET _RATE	double	Equivalent to RA_OFFSET_RATE, but for an offset rate in azimuth.	as/s	No
EL_OFFSET _RATE	double	Equivalent to DEC_OFFSET_RATE, but for an offset rate in elevation.	as/s	No
TRACK_RA TE_FACTO R	double	Offers option to specify tracking at a track rate which is a multiple or fraction of the track rate defined by TRACK_RATE_TYPE. Not applicable for TRACK_RATE_TYPE “none”. Only positive values are allowed. Does not apply to previously added RA_OFFSET_RATE and DEC_OFFSET_RATE. These may be added in addition, but are not subject to the TRACK_RATE_FACTOR.	-	No
REFERENC E_FRAME	double	Reference frame of the provided coordinates. Allowed values at the moment are “J2000”, “ICRF”, “horizontal”. Default is “J2000”.	-	No
ORIGIN	String	Origin of the equatorial coordinate system. Either “topocentric” or “geocentric”. Default is “topocentric”.	-	No
velocity segment				No
KM_SEC	double	Radial velocity of target in km/s e.g. for radar observations	km/ s	No
REDSHIFT	double	Radial velocity of target in redshift	-	No

7.5.6 calibrationObservation segment

(not mandatory, either calibrationObservation or observation allowed)

Keyword	Type	Description	Unit	Mandator y
BIAS_CAPTURE	Boolean	Indicates that a bias exposure shall be taken, i.e. the capture of an image with a closed shutter and the shortest possible exposure time. Detailed instructions must be provided by the telescope/server. Only one of BIAS_CAPTURE, FLATFIELD_CAPTURE, and SPECTRAL_CALIBRATION		No

		allowed in one calibrationObservation segment.		
FLATFIELD_CAPTURE	boolean	Indicates that a series of flat field exposures shall be taken, i.e. an image of a uniform reference field. Detailed instructions of the flat field location etc. must be provided by the telescope/server.		No
SPECTRAL_CALIBRATION	boolean	Indicates that a spectral calibration using arc lamps available at the specific telescope shall be carried out. Detailed instructions must be provided by the telescope/server.		No
ARC_LAMP	string	Offers the possibility to choose among different arc lamps / spectral calibration procedures available at the individual telescope. Entries shall not be case-sensitive.		No
DATE_TIME_START	dateTime	Date and time when the calibration observation shall be carried out. In ISO DateTime format (yyyy-mm-ddThh:mm:ss.sss). Not mandatory if the calibrationObservation segment is within a scheduleRequest.		Yes
TIME_START_TOLERANCE	duration	Tolerance (+/-) around DATE_TIME_START when the calibration observation may be carried out. If no tolerance is provided, it is assumed to be 1s.		No

7.5.7 exposure segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
EXPOSURE_TIME	double	Exposure time	s	Yes
EXPOSURE_COUNT	integer	Number of consecutive exposures to be taken. If not specified, one single exposure is assumed. Dithering in between them can be defined using the dithering segment. Individual image file names are appended		No

		according to the settings of the specific telescope (e.g. by “_x”, with x being the running exposure number)		
DELAY	duratio n	Delay between individual exposures if the value of EXPOSURE_COUNT is >1. If no DELAY is specified, the telescope shall take the next exposure as soon as possible. Does not specify delay between the last exposure of one “command” or “scheduleRequest” and the first one of the next.		no
TOLERANCE	duratio n	Optional tolerance in the delay between one exposure and the next exposure. If TOLERANCE is not provided, it is assumed to be 1s.		no
dithering segment		Allows the user to set a dithering pattern in between consecutive exposures requested using EXPOSURE_COUNT, either by choosing a pre-set pattern of the telescope or submitting a user-defined one with RA_OFFSET and DEC_OFFSET.		No
DITHER_MODE	string	Offers possibility to choose a dithering mode defined by and made available at the individual telescope. Entries shall not be case-sensitive. Either DITHER_MODE or RA_OFFSETS and DEC_OFFSETS may be used.		No
RA_OFFSET	double	Offsets from the target position in RA for each consecutive exposure. Exactly as many RA_OFFSET elements must exist as exposures are requested in EXPOSURE_COUNT. Each offset must refer to the original target position. RA_OFFSET and DEC_OFFSET are grouped according to the order of appearance. If only an offset in one direction is desired, the offset in the other direction must be specified as “0”.	as	No
DEC_OFFSET	double	Offsets from the target position in declination for each consecutive exposure. Exactly as many DEC_OFFSET elements must exist as exposures are requested in EXPOSURE_COUNT. Each offset must refer to the original target position. RA_OFFSET and DEC_OFFSET are grouped according to the order of appearance.	as	No
AZ_OFFSET	double	Equivalent to RA_OFFSET, but for offset in azimuth	as	No
EL_OFFSET	double	Equivalent to DEC_OFFSET, but for offset in	as	No

		elevation		
REFERENCE_FRAME	double	Reference frame of the provided coordinates. Allowed values at the moment are "J2000", "ICRF", "horizontal". Default is "J2000".	-	No
ORIGIN	String	Origin of the equatorial coordinate system. Either "topocentric" or "geocentric". Default is "topocentric".	-	No

7.5.8 observation segment

(not mandatory, either observation or calibrationObservation allowed)

Keyword	Type	Description	Unit	Mandatory
DATE_TIME_START	dateTime	Date and time when the observation shall be carried out. In ISO DateTime format (yyyy-mm-ddThh:mm:ss.sss).		Yes
TIME_START_TOLERANCE	duration	Tolerance (+/-) around DATE_TIME_START when the observation may be carried out. If no tolerance is provided, it is assumed to be 1s. Can be set for all observations in commonData		No
DATE_TIME_END	dateTime	Optional absolute time before which no other commands/actions are carried out (set position/tracking movement is continued). In ISO DateTime format (yyyy-mm-ddThh:mm:ss.sss).		No
TIME_END_TOLERANCE	duration	Tolerance (+/-) around DATE_TIME_END when the next action may be carried out. If no tolerance is provided, it is assumed to be 1s		No
DELAY	duration	Optional time after the end of the exposure time for which the telescope remains in its current position/tracking movement and no other action is carried out. If a negative DELAY is provided, the telescope shall begin the specified tracking at the DELAY time before the actual exposure. Two DELAY elements, with one providing a positive and one providing a negative value may be included.		No
TOLERANCE	duration	Optional tolerance in the delay between the last exposure of a command/scheduleRequest and the next action (e.g. next exposure). If TOLERANCE is not provided, it is assumed to be 1s.		No

7.6 Definition of the segment 'scheduleRequest'

TSM scheduleRequest segments offer the possibility to provide a telescope scheduler with the necessary information to allocate a requested observation at a suitable time.
The TSM scheduleRequest segment is not mandatory, but at least one TSM command or TSM scheduleRequest segment must be contained in a TSM.
Figure 12 shows the available second-level elements in a TSM scheduleRequest. Each element and its sub-segments are explained in further detail thereafter.

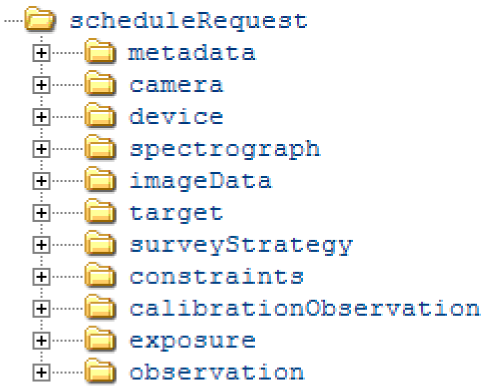


Figure 12: Available 2nd level elements in a TSM scheduleRequest

7.6.1 blockMetadata segment

Keyword	Type	Description	Unit	Mandatory
BLOCK_ID	string	Unique ID of the scheduleRequest		No
STATE	string	State of the scheduleRequest. "1" indicates that the observation has been successfully completed, "0" that is has not been successfully completed.		No
FAIL_COUNT	string	Number of failed attempts to execute the requested observation. Mostly useful for robotic telescopes.		No
PRIORITY	Double	Relative priority of the individual scheduleRequest. No specific scale is predetermined, thus valid scales of the targeted telescope/organisation can be used.		No
linkedBlock segment		Allows scheduleRequests to be linked, e.g. if the success of one block also depends on the success of others. The particular message to which a waitConstraint may apply is defined in the waitConstraint segment.		No

BLOCK_ID	string	Block ID of linked scheduleRequest. linkedBlock segment may contain several BLOCK_ID elements. *If no block with the stated BLOCK_ID exists, and REPEAT_ALL is false, the missing block shall be ignored. In the same case, if REPEAT_ALL is true, the current observation and all other linked messages shall be marked and treated as unsuccessful.*		Yes
REPEAT_ALL	Boolean	Indicates whether in case the observation of one of the linked blocks fails, all linked blocks shall be executed again/whether the success of one block depends on the success of all other linked blocks. If not listed, default state is "false".		No

7.6.2 *camera segment*

(*see camera segment* under TSM command in section 7.5)

7.6.3 *device segment*

(see *device segment* under TSM command in section 7.5)

7.6.4 *spectrograph segment*

(see *spectrograph segment* under TSM command in section 7.5)

7.6.5 *imageData segment*

(see *imageData segment* under TSM command in section 7.5)

7.6.6 *target segment*

(see *target segment* under TSM command in section 7.5)

7.6.7 *surveyStrategy segment*

(not mandatory)[7]

Keyword	Type	Description	Unit	Mandatory
SURVEY_STRATEGY_TYPE	int	Allows choice of several available survey strategy types using the respective integer: ▪ 1-Vertical strip Pointing to a close-to-Anti Sun	-	Yes

[7] See also section 10.5 for a more detailed overview of requirements for different survey strategy types.

		direction (typical strategy for ground based SST GEO, also suitable for space-based GEO observations) ▪ 2-Horizontal strip (typical for ground based SST MEO) ▪ 3-Free Mosaic in inertial reference frame for GB telescopes (typical for NEO observation and also suitable for more flexible SST observations if needed) ▪ 4- Other. If selected, the name of the strategy (available at the telescope) needs to be provided in OTHER_STRATEGY_NAME, and the input values for the strategy in "OTHER_STRATEGY_VALUES"		
IMAGES_PER_TRACK	int	Number of images forming a track, i.e. taken consecutively with the same coordinates (for SST: minimum 3). Not mandatory with SURVEY_STRATEGY_TYPE 4	-	Yes
IMAGES_PER_STRIP	int	Only applicable and mandatory with SURVEY_STRATEGY_TYPE = 1 or 2. Number of images per strip.	-	Partly
NUMBER_OF_STRIPS	int	Number of strips to be observed. Value of "0" indicates that the survey shall be run as long as possible. Not mandatory with SURVEY_STRATEGY_TYPE 4.	-	Yes
INITIAL_RA	double	Initial right ascension of the survey strip. Not mandatory with SURVEY_STRATEGY_TYPE 4.	deg	Yes
INITIAL_DEC	double	Initial declination of the survey strip. (May be smaller or larger than END_DEC) No mandatory with SURVEY_STRATEGY_TYPE 4.	deg	Yes
DELTA_RA_IMAGE	double	Angular separation in right ascension between two consecutive images (or tracks). Mandatory if SURVEY_STRATEGY_TYPE = 3. For SURVEY _STRATEGY_TYPE = 2, one of END_RA and DELTA_RA_IMAGE is mandatory. Survey moves in increasing RA direction from INIT_RA if positive, in decreasing RA direction if negative.	deg	Partly
DELTA_DEC_IMAGE	double	Angular separation in declination between two consecutive images (or tracks). Mandatory if SURVEY_STRATEGY_TYPE = 1 or 3. Survey moves in increasing DEC direction from INIT_DEC if positive, in decreasing DEC direction if negative.	deg	Partly
DELTA_RA_STRIP	double	Optional angular separation in right ascension between the first images of two consecutive strips.	deg	No
DELTA_DEC_STRIP	double	Optional angular separation in declination between the first images of two consecutive strips.	deg	No
ANG_SEPARATION_IMAGE	double	Optional angular separation between two consecutive images as seen from the telescope without taking into account a change in declination between these two	deg	No

		images. Scales roughly with 1/cos(DEC).		
ANG_SEPARATION_STRIP	double	Optional angular separation between two consecutive strips as seen from the telescope without taking into account a change in declination between these two strips. Scales roughly with 1/cos(DEC)	deg	No
ANTI_SUN_OFFSET	double	Angular offset for anti-Sun pointing (mandatory if SURVEY_STRATEGY_TYPE = 1)	deg	Partly
TIME_TRACK_IMAGES	duration	Time between two images of the same track. Must be larger than EXPOSURE_TIME. If not defined, telescope default wait time between exposures shall be used.		No
TIME_CONSECUTIVE_STRIPS	duration	Minimum time that must have passed after the start of the previous strip's observation before the observation of the next strip is started. If the observation of a strip takes longer than TIME_CONSECUTIVE_STRIPS, TIME_CONSECUTIVE_STRIPS is ignored.		No
PRIMARY_DIRECTION	string	Sets the primary direction of movement through a survey field for survey type 3. Allowed values are "RA" and "DEC". Mandatory if SURVEY_STRATEGY_TYPE = 3.	-	Partly
PATTERN	string	Sets the pattern in which a survey field is moved through for survey type 3. Allowed values are "s" and "lines". If PATTERN is not set, the default is "lines".	-	No
REFERENCE_FRAME	double	Reference frame of the provided coordinates. Allowed values at the moment are "J2000", "ICRF", "horizontal". Default is "J2000".	-	No
ORIGIN	String	Origin of the equatorial coordinate system. Either "topocentric" or "geocentric". Default is "topocentric".	-	No
OTHER_STRATEGY_NAME	string	Name of a survey strategy offered by the telescope operator. To be considered, Element only allowed if SURVEY_STRATEGY_TYPE is "4".		No
OTHER_STRATEGY_VALUES	string	List of the available/required input values for the observation strategy (as offered by the telescope operator). Input parameters and their values must be provided in keyword=value notation, with different keyword-value-pairs separated by comas. Element only allowed if SURVEY_STRATEGY_TYPE is "4".		No

7.6.8 constraints segment

(not mandatory) Holds all the following elements defining observation constraints

7.6.8.1 airmassConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
AIRMASS	double	Maximum acceptable airmass relative to that at the zenith at sea level.		No
CONSTRAINT_TYPE	string	Allowed values are “greater”, “less”, or “equal”. “greater” indicates that the directly preceding AIRMASS element shall be interpreted as a minimum airmass. “less” indicates that the directly preceding AIRMASS element shall be interpreted as maximum airmass. “equal” indicates that the airmass should be exactly equal to AIRMASS. If not provided, default is “less”.		No

7.6.8.2 dateTimeConstraint segment

(not mandatory) Several dateTimeConstraint segments may be used within one scheduleRequest to define multiple time intervals during which the observation may be carried out.

Keyword	Type	Description	Unit	Mandatory
DATE_TIME_START	dateTime	Earliest time of the observation. In ISO DateTime format (yyyy-mm-ddThh:mm:ss.sss).		No
DATE_TIME_END	dateTime	Latest time the observation shall be performed. In ISO DateTime format (yyyy-mm-ddThh:mm:ss.sss).		No

7.6.8.3 eclipticConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
DISTANCE	double	Minimum required angular distance between the target and the ecliptic. May also be used to require a maximum angular distance if followed by a CONSTRAINT_TYPE element.	deg	No
CONSTRAINT_TYPE	string	Allowed values are “greater”, “less”, or “equal”. “greater” indicates that the directly preceding DISTANCE element shall be interpreted as a minimum angular distance. “less” indicates that the directly preceding DISTANCE element shall be interpreted as a maximum angular distance. “equal” indicates that the angular distance should		No

		be exactly equal to DISTANCE. If not provided, default is "greater".		

7.6.8.4 exposureConstraint segment

(not mandatory)

Keyword	Type	De;scription	Unit	Mandatory
EXPOSURE_COUNT	integer	Number of consecutive exposures to be taken. If not specified, one single exposure is assumed. Individual image file names are appended according to the settings of the specific telescope (e.g. by "_x", with x being the running exposure number)		No
SIGNAL_TO_NOISE	double	Minimum signal to noise ratio required for the observation. If the telescope operator supports this service, he will adapt the exposure time accordingly. May also be used to indicate a maximum signal to noise (e.g. to define an interval) if followed by a CONSTRAINT_TYPE element).		No
CONSTRAINT_TYPE	string	Allowed values are "greater", "less", or "equal". "greater" indicates that the directly preceding SIGNAL_TO_NOISE element shall be interpreted as a minimum required signal to noise ratio. "less" indicates that the directly preceding SIGNAL_TO_NOISE element shall be interpreted as a maximum signal to noise ratio. "equal" indicates that the signal to noise ratio should be exactly equal to SIGNAL_TO_NOISE. If not provided, default is "greater".		No

7.6.8.5 fieldOfViewConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
FIELD_OF_VIEW	double	If submitting an observation request to a network of telescopes (rather than a specific telescope), this constraint can be used to specify the minimum field of view diameter the actually	as	No

		used telescope shall have. Can also be used to specify a maximum field of view diameter if followed by a CONSTRAINT_TYPE element.		
CONSTRAINT_ TYPE	string	Allowed values are “greater”, “less”, or “equal”. “greater” indicates that the directly preceding FIELD_OF_VIEW element shall be interpreted as a minimum required field of view. “less” indicates that the directly preceding SIGNAL_TO_NOISE element shall be interpreted as a maximum allowed field of view. “equal” indicates that the field of view should be exactly equal to FIELD_OF_VIEW. If not provided, default is “greater”.	as	No

7.6.8.6 galacticPlaneConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
DISTANCE	double	Minimum required angular distance between the target and the galactic plane. May also be used to require a maximum angular distance if followed by a CONSTRAINT_TYPE element.	deg	No
CONSTRAINT_ TYPE	string	Allowed values are “greater”, “less”, or “equal”. “greater” indicates that the directly preceding DISTANCE element shall be interpreted as a minimum angular distance. “less” indicates that the directly preceding DISTANCE element shall be interpreted as a maximum angular distance. “equal” indicates that the angular distance should be exactly equal to DISTANCE. If not provided, default is “greater”.		No

7.6.8.7 informationGainConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
interval segment		Contains the expected relative information gain for a certain time interval during which the		Yes

		requested observation may be carried out. Thereby allows to indicate preferred times for an observation. An informationGainConstraint segment will usually contain more than one interval segment. Mainly used for Space Debris observations.		
DATE_TIME_START	dateTime	Start of the time interval		No
DATE_TIME_END	dateTime	End of the time interval		No
INFORMATION_GAIN	double	Expected relative information gain if the requested observation was carried out within the interval. The INFORMATION_GAIN value may, e.g., be a decimal value between 0 and 1.		Yes

7.6.8.8 moonConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
DISTANCE	double	Minimum required angular distance between the target and the moon. May also be used to require a maximum angular distance if followed by a CONSTRAINT_TYPE element.	deg	No
CONSTRAINT_TYPE	string	Allowed values are "greater", "less", or "equal". "greater" indicates that the directly preceding DISTANCE element shall be interpreted as a minimum angular distance. "less" indicates that the directly preceding DISTANCE element shall be interpreted as a maximum angular distance. "equal" indicates that the angular distance should be exactly equal to DISTANCE. If not provided, default is "greater".		No
PHASE	double	Maximum acceptable lunar phase as a decimal value between 0 and 1 (0 being new moon, 1 full moon). May also be used to require a minimum lunar phase if followed by a COSNTRAINT_TYPE element.		No
CONSTRAINT_TYPE	string	Allowed values are "greater", "less", or "equal". "greater" indicates that the directly preceding PHASE element shall be interpreted as a minimum required lunar phase. "less" indicates that the directly preceding DISTANCE element		No

		shall be interpreted as a maximum lunar phase. "equal" indicates that the lunar phase should be exactly equal to PHASE. If not provided, default is "less".		

7.6.8.9 nightConstraint segment

(not mandatory) Several nightConstraint segments may be used within one scheduleRequest to define multiple intervals during which observations may be carried out, or to define the start and end times of one interval relative to different twilight types.

Keyword	Type	Description	Unit	Mandatory
BEGIN_NIGHT	duration	Time after (positive value) or before (negative value) the beginning of the night from which on the observation may be carried out. By default, the beginning of the night is at the end of astronomical evening twilight, unless otherwise defined in the TWILIGHT_TYPE parameter. Can also be used to require that observations must be finished by the indicated time or start exactly at the indicated time if followed by a CONSTRAINT_TYPE element.		No
CONSTRAINT_TYPE	string	Allowed values are "greater", "less", or "equal". "grater" indicates that the observation must occur after the time indicated by BEGIN_NIGHT. "less" means that the observation must be finished before the time indicated by BEGIN_NIGHT . "equal" means that the observation must start at the time indicated by BEGIN_NIGHT. If not provided, "greater" is assumed as default.		No
END_NIGHT	duration	Time after (positive value) or before (negative value) the end of the night by which the observation must be finished. By default, the end of the night is at the beginning of astronomical morning twilight, unless otherwise defined in the TWILIGHT_TYPE parameter. Can also be used to require an observation to start after or exactly at the indicated time if followed by a CONSTRAINT_TYPE element.		No
CONSTRAINT_TYPE	string	Allowed values are "greater", "less", or "equal". "greater" indicates that the observation must occur after the time indicated by END_NIGHT.		No

		"less" means that the observation must be finished before the time indicated by END_NIGHT . "equal" means that the observation must start at the time indicated by END_NIGHT. If not provided, "less" is assumed as default.		
TWILIGHT_TYPE	string	Specifies the type of twilight the BEGIN_NIGHT and the END_NIGHT elements refer to. Accepted values are "astronomical"- sun 18 deg below the horizon, "nautical"- sun 12 deg below the horizon, "civil" – sun 6 deg below the horizon. Only applicable within the parent "nightConstraint" element. If not specified, the default value is "astronomical".	-	No

7.6.8.10 sunConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
DISTANCE	double	Maximum allowed angle between the object-telescope and the object-sun vectors (in case the telescope operator supports it). May also be used to require a minimum angular distance if followed by a CONSTRAINT_TYPE element.	deg	No
CONSTRAINT_TYPE	string	Allowed values are "greater", "less", or "equal". "greater" indicates that the directly preceding DISTANCE element shall be interpreted as a minimum angular distance. "less" indicates that the directly preceding DISTANCE element shall be interpreted as a maximum angular distance. "equal" indicates that the angular distance should be exactly equal to DISTANCE. If not provided, default is "less".		No

7.6.8.11 waitConstraint segment

(not mandatory)

Keyword	Type	Description	Unit	Mandatory
PREVIOUS_BL	string	NAME of the scheduleRequest after which the		Either

OCK		event described in this scheduleRequest shall follow. Element is only relevant if the waitConstraint segment is located in a schedulerRequest segment.		PREVIOUS_BLOCK or PREVIOUS MESSAGE
PREVIOUS_MESSAGE	string	Message ID of the TSM file after which the event described in the TSM file shall follow. Element is only relevant if the waitConstraint segment is located in a linkedTSM segment of a metadata segment (see section 0)		Either PREVIOUS_BLOCK or PREVIOUS MESSAGE
WAIT_TIME	duration	Time that shall have passed after the completion of a previous scheduleRequest (or another TSM file). The previous request is identified by its NAME or MESSAGE_ID. Allows e.g. the request for an observation of the same target twice with an hour difference or the request for a CALIBRATION_OBSERVATION right before the observation. Can also be used to indicate a maximum or minimum wait time if followed by a CONSTRAINT_TYPE element.		No
CONSTRAINT_TYPE	string	Allowed values are “greater”, “less”, or “equal”. “greater” means that WAIT_TIME is interpreted as a minimum wait time. “less” means that WAIT_TIME is interpreted as a maximum wait time. “equal” means that the observations should be separated exactly (taking into account TOLERANCE) the WAIT_TIME. If not provided, the default is “equal”.		No
TOLERANCE	duration	Optional tolerance of the WAIT_TIME. If no TOLERANCE is provided, it is assumed to be 1s.		No

7.6.8.12 Other Constraints

Keyword	Type	Description	Unit	Mandatory
EXTINCTION_CONSTRAINT	string	Describes maximum allowable cloud conditions by a list of general descriptions: clear, light, scattered, heavy.		No

SEEING_CONSTRAINT	double	Maximum allowable seeing.	as	No
STREHL_CONSTRAINT	double	Minimum required Strehl ratio for the observation in case a telescope with adaptive optics is used (as a decimal number between 0 and 1, with 1 being that of a perfect imaging system)		No
WATER_VAPOR_CONSTRAINT	double	Constraint on the maximum amount of precipitable water vapour that may be in the atmosphere over the optical path at the time of the observation (applies for near- and mid-IR observations)	mm	No

7.6.9 calibrationObservation segment

(see *calibrationObservation segment* under TSM command in section 7.5, only DATE_TIME_START does not apply)

7.6.10 exposure segment

(see *exposure segment* under TSM command in section 7.5). Not mandatory.

7.6.11 observation segment

(see *observation segment* under TSM command in section 7.5, only DATE_TIME_START and DATE_TIME_END do not apply)

7.7 Macros

Macros allow certain parts of a TSM to be reused without writing them in their entirety every time. They are parts of a TSM structure, e.g. a target definition in form of the “target” element. If in this example the same target is used by some, but not all, “commands” in a TSM, it only has to be defined once within the “macros” segment of the TSM commonData. In this case, the entire “target” element with all its child elements would be included in the “macros” segment and assigned a unique “id=…” attribute. It can then be called at another point in the message by referring to its id with the corresponding “ref=…” or “uref=…” attribute in the definition of a target element, instead of listing all the child elements again.
Macros must comply to the hierarchy at the point where they are called.

An example of a definition would be the following:

```
<macros>
    <target id=”target_1”>
        <coordinates>
            <RA>0.128194</RA>
            <DEC>0.693649</DEC>
```

```
        </coordinates>
    </target>
</macros>
```

Instead of providing the entire information again in a subsequent scheduleRequest segment, the predefined target would be linked in the following way:

```
<scheduleRequest>
    …
    <imageData>
        <…>
    </imageData>
    <target ref=”target_1”/>
    …
</scheduleRequest>
```

8 EXAMPLES

8.1 Commanding a Series of Observations

In many cases, one would like to conduct a series of observations, with only a subset of the parameters changing from observation to observation. This could be, for example, the use of different filters on the same target, or a survey taking exposures of a number of areas in the sky.
In these cases, it would be a relatively large effort to list all the information again for each individual exposure. Thus, it shall be possible to define part of the information globally for all observations, and the changing information for each observation individually.
The following example visualizes how this can be implemented for a survey that takes five subsequent exposures of neighbouring parts of the sky.
As figure 13 illustrates, the parameters valid for all observations are defined in the upper part of the document: four FITS header keywords, the camera to be used, the type of tracking, and the epoch of the target coordinates.
The changing parameters, namely the file names, the target coordinates, and the absolute times for the observations are defined in the lower part of the document in separate "*command*" elements.

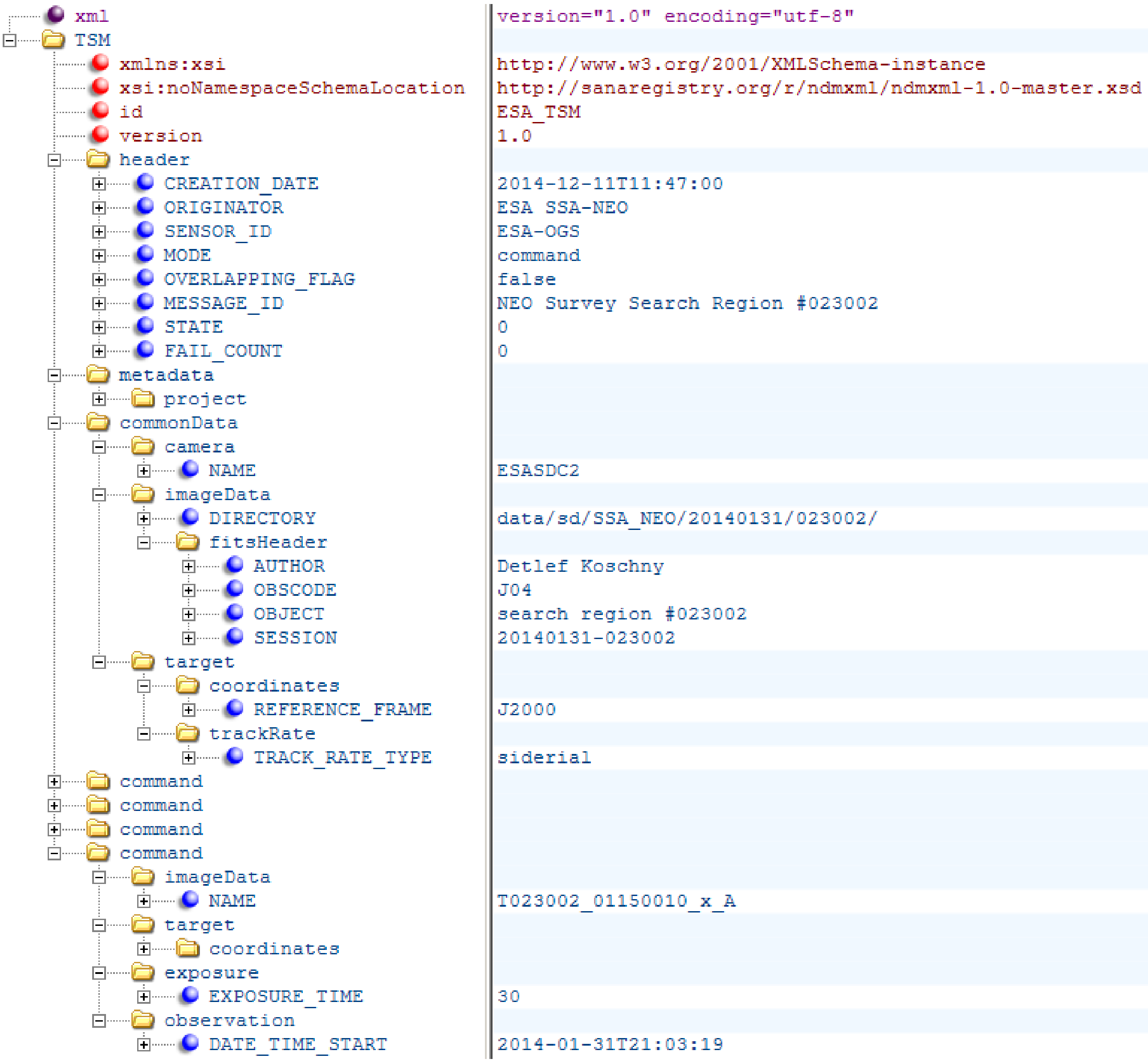


Figure 13 Example of a telescope command file for a series of observations with a subset of changing parameters

The ASCII code of the document reveals the entire information:

```
<TSM xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-
    1.0-master.xsd" id="ESA_TSM" version="1.0">

  <header>
      <CREATION_DATE>2014-12-11T11:47:00</CREATION_DATE>
      <ORIGINATOR>ESA SSA-NEO</ORIGINATOR>
      <SENSOR_ID>ESA-OGS</SENSOR_ID>
```

```
        <MODE>command</MODE>
        <OVERLAPPING_FLAG>false</OVERLAPPING_FLAG>
        <MESSAGE_ID>NEO Survey Search Region #023002</MESSAGE_ID>
        <STATE>0</STATE>
        <FAIL_COUNT>0</FAIL_COUNT>
    </header>

    <metadata>
        <project>
            <PROJECT_ID>SSA-NEO</PROJECT_ID>
            <TITLE>TOTAS</TITLE>
            <PRIORITY>2</PRIORITY>
            <contact>
                <NAME>Detlef Koschny</NAME>
                <USERNAME>Detlef Koschny/estec/ESA</USERNAME>
                <INSTITUTION>European Space Agency</INSTITUTION>
                <ADDRESS>Keplerlaan 1, PO Box 299, NL-2200 AG
                    Noordwijk</ADDRESS>
                <COUNTRY_CODE>NL</COUNTRY_CODE>
                <EMAIL>Detlef.Koschny@esa.int</EMAIL>
                <TELEPHONE>+31 71 565 4828</TELEPHONE>
                <FAX>+31 71 565 4828</FAX>
                <PRINCIPAL_INVESTIGATOR>true</PRINCIPAL_INVESTIGATOR>
            </contact>
        </project>
    </metadata>

    <commonData>
        <camera>
            <NAME>ESASDC2</NAME>
        </camera>
        <imageData>
            <DIRECTORY>data/sd/SSA_NEO/20140131/023002/</DIRECTORY>
            <fitsHeader>
                <AUTHOR>Detlef Koschny</AUTHOR>
                <OBSCODE>J04</OBSCODE>
                <OBJECT>search region #023002</OBJECT>
                <SESSION>20140131-023002</SESSION>
            </fitsHeader>
        </imageData>
        <target>
            <coordinates>
                <REFERENCE_FRAME>J2000</REFERENCE_FRAME>
            </coordinates>
            <trackRate>
                <TRACK_RATE_TYPE>siderial</TRACK_RATE_TYPE>
            </trackRate>
        </target>
    </commonData>
```

```
<command>
     <imageData>
          <NAME> T023002_01150010_x_A</NAME>
     </imageData>
     <target>
          <coordinates>
               <RA>0.127778</RA>
               <DEC>0.536952</DEC>
          </coordinates>
     </target>
     <exposure>
          <EXPOSURE_TIME>30</EXPOSURE_TIME>
     </exposure>
     <observation>
          <DATE_TIME_START>2014-01-31T21:01:17</DATE_TIME_START>
     </observation>
</command>

<command>
     <imageData>
          <NAME> T023002_01150011_x_A</NAME>
     </imageData>
     <target>
          <coordinates>
               <RA>0.128194</RA>
               <DEC>0.589203</DEC>
          </coordinates>
     </target>
     <exposure>
          <EXPOSURE_TIME>30</EXPOSURE_TIME>
     </exposure>
     <observation>
          <DATE_TIME_START>2014-01-31T21:01:59</DATE_TIME_START>
     </observation>
</command>

<command>
     <imageData>
          <NAME> T023002_01150012_x_A</NAME>
     </imageData>
     <target>
          <coordinates>
               <RA>0.128194</RA>
               <DEC>0.641426</DEC>
          </coordinates>
     </target>
     <exposure>
          <EXPOSURE_TIME>30</EXPOSURE_TIME>
     </exposure>
```

```
        <observation>
            <DATE_TIME_START>2014-01-31T21:02:39</DATE_TIME_START>
        </observation>
    </command>

    <command>
        <imageData>
            <NAME> T023002_01150013_x_A</NAME>
        </imageData>
        <target>
            <coordinates>
                <RA>0.128194</RA>
                <DEC>0.693649</DEC>
            </coordinates>
        </target>
        <exposure>
            <EXPOSURE_TIME>30</EXPOSURE_TIME>
        </exposure>
        <observation>
            <DATE_TIME_START>2014-01-31T21:03:19</DATE_TIME_START>
        </observation>
    </command>
</TSM>
```


8.2 Requesting Follow-Up observations two hours apart

The following example shall illustrate how a submission to an automatic scheduler might look like, including typical constraints on an observation and a linkage between two observations that should be carried out with a defined temporal distance. If the two observations are submitted as separate scheduleRequests, as illustrated in this example, the scheduler should treat them as different blocks and place other requested observations in between them.

```
xml                                     version="1.0" encoding="utf-8"
TSM
    xmlns:xsi                           http://www.w3.org/2001/XMLSchema-instance
    xsi:noNamespaceSchemaLocation       http://sanaregistry.org/r/ndmxml/ndmxml-1.0-master.xsd
    id                                  ESA_TSM
    version                             1.0
    header
    metadata
    commonData
    scheduleRequest
        metadata
            JOB_ID                      Follow-Up_2015BD515-1_SSA-NEO_Slot54-04
            STATE                       0
            FAIL_COUNT                  0
            PRIORITY                    2
        imageData
        target
            NAME                        2015BD515
            TARGET_TYPE                 NEO
            ephemerides
                EPHEMERIDES_TYPE        SSA ID
                URI                     http://newton.dm.unipi.it/neodys/where-is-2015BD515?
        constraints
            dateTimeConstraint
                DATE_TIME_START         2015-03-20T18:00:00
                DATE_TIME_END           2015-03-21T09:00:00
            moonConstraint
                DISTANCE                90
            nightConstraint
                BEGIN_NIGHT             -PT3M
                END_NIGHT               PT3M
        exposure
            EXPOSURE_TIME               35
            EXPOSURE_COUNT              15
    scheduleRequest
        metadata
            JOB_ID                      Follow-Up_2015BD515-2_SSA-NEO_Slot54-04
            STATE                       0
            FAIL_COUNT                  0
            PRIORITY                    2
            linkedJob
                JOB_ID                  Follow-Up_2015BD515-1_SSA-NEO_Slot54-04
                REPEAT_ALL              true
        imageData
        target
        constraints
            dateTimeConstraint
            moonConstraint
            waitConstraint
                PREVIOUS_JOB            Follow-Up_2015BD515-1_SSA-NEO_Slot54-04
                WAIT_TIME               PT2H
                TOLERANCE               600
            nightConstraint
        exposure
```


Figure 14: Example of a telescope scheduler request file for two linked blocks

The ASCII code of the document again reveals the entire information:


```xml
<TSM xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-
   1.0-master.xsd" id="ESA_TSM" version="1.0">

   <header>
      <CREATION_DATE>2015-03-20T18:00:00</CREATION_DATE>
      <ORIGINATOR>ESA SSA-NEO</ORIGINATOR>
      <SENSOR_ID>ESA-OGS</SENSOR_ID>
      <MODE>request</MODE>
      <OVERLAPPING_FLAG>false</OVERLAPPING_FLAG>
      <MESSAGE_ID>SSA-NEO_Slot54-04</MESSAGE_ID>
      <STATE>0</STATE>
      <FAIL_COUNT>0</FAIL_COUNT>
   </header>
   <metadata>
      <project>
         <PROJECT_ID>SSA-NEO</PROJECT_ID>
         <TITLE>TOTAS</TITLE>
         <PRIORITY>2</PRIORITY>
         <contact>
            <NAME>Detlef Koschny</NAME>
            <USERNAME>Detlef Koschny/estec/ESA</USERNAME>
            <INSTITUTION>European Space Agency</INSTITUTION>
            <ADDRESS>Keplerlaan 1, PO Box 299, NL-2200 AG
               Noordwijk</ADDRESS>
            <COUNTRY_CODE>NL</COUNTRY_CODE>
            <EMAIL>Detlef.Koschny@esa.int</EMAIL>
         </contact>
      </project>
   </metadata>
   <commonData>
      <camera>
         <NAME>ESASDC2</NAME>
         <detector>
            <chips>
               <chip id="0">
                  <windowing>
                     <lowerLeft>
                        <X>50</X>
                        <Y>4</Y>
                     </lowerLeft>
                  </windowing>
               </chip>
            </chips>
            <binning>
               <X>2</X>
               <Y>2</Y>
            </binning>
            <FLUSH_RATIO>1</FLUSH_RATIO>
```

```
                <READOUT_SPEED>6.1</READOUT_SPEED>
                <SENSITIVITY>3</SENSITIVITY>
            </detector>
            <filterWheel>
                <filter>
                    <NAME>IR block</NAME>
                    <FILTER_TYPE>clear</FILTER_TYPE>
                </filter>
            </filterWheel>
            <shutter>
                    <MODE>1</MODE>
            </shutter>
        </camera>
    <imageData>
        <DIRECTORY>data/sd/SSA_NEO/20150320/</DIRECTORY>
        <fitsHeader>
            <SIMPLE>T</SIMPLE>
            <BITPIX>16</BITPIX>
            <NAXIS>2</NAXIS>
            <NAXIS1>2056</NAXIS1>
            <NAXIS2>2056</NAXIS2>
            <BZERO>32768</BZERO>
            <BSCALE>1</BSCALE>
            <EXTEND>T</EXTEND>
            <TELESCOP>OGS</TELESCOP>
            <OBSCODE>J04</OBSCODE>
            <SITELAT>28.29822</SITELAT>
            <SITELONG>343.49071</SITELONG>
            <ELEVATIO>2400</ELEVATIO>
            <APTDIA>1020</APTDIA>
            <OBSTRUC>0.1</OBSTRUC>
            <FOCALLEN>4400</FOCALLEN>
            <NREFLECT>2</NREFLECT>
            <TRACKING>sidereal</TRACKING>
            <INSTRUME>ESASDC2</INSTRUME>
            <XBINNING>2</XBINNING>
            <YBINNING>2</YBINNING>
            <GAIN>0.9</GAIN>
            <FILTER>IRBlock</FILTER>
            <EQUINOX>2000</EQUINOX>
            <SCALE>0.69</SCALE>
            <CAMPAIGN>SSA-NEO OGS slot 54-04</CAMPAIGN>
            <SESSION>54-04</SESSION>
        </fitsHeader>
    </imageData>
    <target>
        <trackRate>
            <TRACK_RATE_TYPE>sidereal</TRACK_RATE_TYPE>
```

```xml
        </trackRate>
        </target>
        <REFERENCE_FRAME>J2000</REFERENCE_FRAME>
    </commonData>
    <scheduleRequest>
        <blockMetadata>
            <BLOCK_ID>Follow-Up_2015BD515-1_SSA-NEO_Slot54-04</BLOCK_ID>
            <STATE>0</STATE>
            <FAIL_COUNT>0</FAIL_COUNT>
            <PRIORITY>2</PRIORITY>
        </blockMetadata>
        <imageData>
            <DIRECTORY>/2015BD515/</DIRECTORY>
            <NAME>2015BD515_20150615-1</NAME>
            <fitsHeader>
                <OBJECT>2015BD515</OBJECT>
            </fitsHeader>
        </imageData>
        <target>
            <NAME>2015BD515</NAME>
            <TARGET_TYPE>NEO</TARGET_TYPE>
            <ephemerides>
                <EPHEMERIDES_TYPE>SSA ID</EPHEMERIDES_TYPE>
                <URI>http://newton.dm.unipi.it/neodys/where-is-
                    2015BD515?</URI>
            </ephemerides>
        </target>
        <constraints>
            <dateTimeConstraint>
                <DATE_TIME_START>2015-03-20T18:00:00</DATE_TIME_START>
                <DATE_TIME_END>2015-03-21T09:00:00</DATE_TIME_END>
            </dateTimeConstraint>
            <moonConstraint>
                <DISTANCE>90</DISTANCE>
            </moonConstraint>
            <nightConstraint>
                <BEGIN_NIGHT>-PT3M</BEGIN_NIGHT>
                <END_NIGHT>PT3M</END_NIGHT>
            </nightConstraint>
        </constraints>
        <exposure>
            <EXPOSURE_TIME>35</EXPOSURE_TIME>
            <EXPOSURE_COUNT>15</EXPOSURE_COUNT>
        </exposure>
    </scheduleRequest>
    <scheduleRequest>
        <blockMetadata>
            <BLOCK_ID>Follow-Up_2015BD515-2_SSA-NEO_Slot54-04</BLOCK_ID>
            <STATE>0</STATE>
```

```
            <FAIL_COUNT>0</FAIL_COUNT>
             <PRIORITY>2</PRIORITY>
            <linkedBlock>
                  <BLOCK_ID>Follow-Up_2015BD515-1_SSA-NEO_Slot54-04
                        </BLOCK_ID>
                  <REPEAT_ALL>true</REPEAT_ALL>
            </linkedBlock>
      </blockMetadata>
      <imageData>
            <DIRECTORY>/2015BD515/</DIRECTORY>
            <NAME>2015BD515_20150615-2</NAME>
            <fitsHeader>
                  <OBJECT>2015BD515</OBJECT>
            </fitsHeader>
      </imageData>
      <target>
            <NAME>2015BD515</NAME>
            <TARGET_TYPE>NEO</TARGET_TYPE>
            <ephemerides>
                  <EPHEMERIDES_TYPE>SSA ID</EPHEMERIDES_TYPE>
                  <URI>http://newton.dm.unipi.it/neodys/where-is-
                        2015BD515?</URI>
            </ephemerides>
      </target>
      <constraints>
            <dateTimeConstraint>
                  <DATE_TIME_START>2015-03-20T18:00:00</DATE_TIME_START>
                  <DATE_TIME_END>2015-03-21T09:00:00</DATE_TIME_END>
            </dateTimeConstraint>
            <moonConstraint>
                  <DISTANCE>90</DISTANCE>
            </moonConstraint>
            <waitConstraint>
                  <PREVIOUS_BLOCK>Follow-Up_2015BD515-1_SSA-NEO_Slot54-
                        04</PREVIOUS_BLOCK>
                  <WAIT_TIME>PT2H</WAIT_TIME>
                  <TOLERANCE>PT10M</TOLERANCE>
            </waitConstraint>
            <nightConstraint>
                  <BEGIN_NIGHT>-PT3M</BEGIN_NIGHT>
                  <END_NIGHT>PT3M</END_NIGHT>
            </nightConstraint>
      </constraints>
      <exposure>
            <EXPOSURE_TIME>35</EXPOSURE_TIME>
            <EXPOSURE_COUNT>15</EXPOSURE_COUNT>
      </exposure>
   </scheduleRequest>
</TSM>
```

9 OPEN ITEMS AND FUTURE IMPROVEMENTS

The following aspects of the format were considered, but shall still be discussed.

Details of delivery method and time
Currently, the format only foresees the choice of a local directory and filename for saving (NAME), the choice of a compression type (COMPRESSION_TYPE) and the choice of a delivery method from a still undefined list (DELIVERY_TYPE) within the imageData segment. Besides in an auxiliaryMessage element, it currently does not foresee the specification of the address of an ftp server the images should be delivered to, the directory on that server, or the time at which an image (or a group of images) shall be delivered.
Whether more functionality should be included and how this could be done without making the format too complicated is still open.

Order of command / scheduleRequest segments
The format currently only requires chronological ordering of command segments, since they are meant to be read out by a telescope control computer of comparatively little complexity. scheduleRequest segments, on the other hand, are not required to be ordered, since in certain scenarios TSM creators may want to order requests not strictly chronologically, but e.g. by object to be observed. This also allows flexibility for particular applications, where parties might agree on grouping observations and their respective calibration observations together, for example.
Whether a certain order should be imposed by the format to ease automated readout, however, should still be discussed.

Commanding of acquisition sequences
TSMs currently do not explicitly support the commanding or request of elaborate acquisition sequences, such as required for spectroscopy. The reason is that, among others, TSM currently does not foresee feedback and active input into a TSM file from the instrument system. At the moment acquisition sequences would have to be commanded in an auxiliaryMessage and the corresponding TSM file of the following observation would probably need to be partly rewritten.
Since commanding of acquisition sequences is necessary for spectroscopy, though, a future issue of the standard shall support it.

Higher level command logic
For scheduleRequest segments, it would be useful and support the efficiency of the standard if more logic commands were foreseen and allowed, e.g. to define loops, to define sequences of exposures with certain settings (e.g. filters) to be executed within one scheduleRequest segment, or even to define dependencies between parameters (e.g. specific filters and exposure times).
The extent to which logical structures shall be permitted within TSMs will have to be a matter of further discussion, however. So will be the question whether logical structures shall also be allowed in command segments or only in scheduleRequest segments. If this is implemented in future versions, the naming of the “macro” segments should be reconsidered in order to avoid confusion among the two features.

Definition of surveyStrategies in different coordinate systems

Currently, the format does not support the definition of surveyStrategies in other coordinate systems than the Right Ascension / Declination system. This concerns especially the definition of space-based surveys in local coordinate systems. At the moment, such a survey thus has to be defined in a different software that already converts the outcome into commands permitted in TSMs.

In future issues, it might be considered to support the change of reference systems.

Notation of constraints

Several constraints available in scheduleRequest elements require the user to specify whether the value provided is an upper or a lower bound. Currently, this is solved by providing an element to define the value, and a subsequent element (CONSTRAINT_TYPE) providing the information whether the earlier value should be regarded as an upper or lower bound or as the exact value, if different from the default setting. It could, alternatively, also be solved by providing separate elements for the lower and upper bound, without the CONSTRAINT_TYPE element. This might be more intuitive and less error-prone, so it should be considered for future issues.

The constraint elements in question are airmassConstraint, eclipticConstraint, exposureConstraint, fieldOfViewConstraint, galacticPlaneConstraint, moonConstraint, nightConstraint, sunConstraint, waitConstraint.

10 APPENDIX

10.1 XML document header

In the following, the document header of an XML document shall be explained concisely. The header carries information on the format of the document, but also information necessary to check the validity of the XML document (through the comparison with an XML grammar). It also lists the document's unique identification code.

As figure 15 shows, the third part of the document header appears in the form of attributes of the root element (shown as red dots in the tree diagram). As the ASCII code of the header below shows, these are written directly into the opening tag of the root element. The content of the attributes is added on the right side in XML Notepad, or in the form *attribute="content"* in ASCII format.

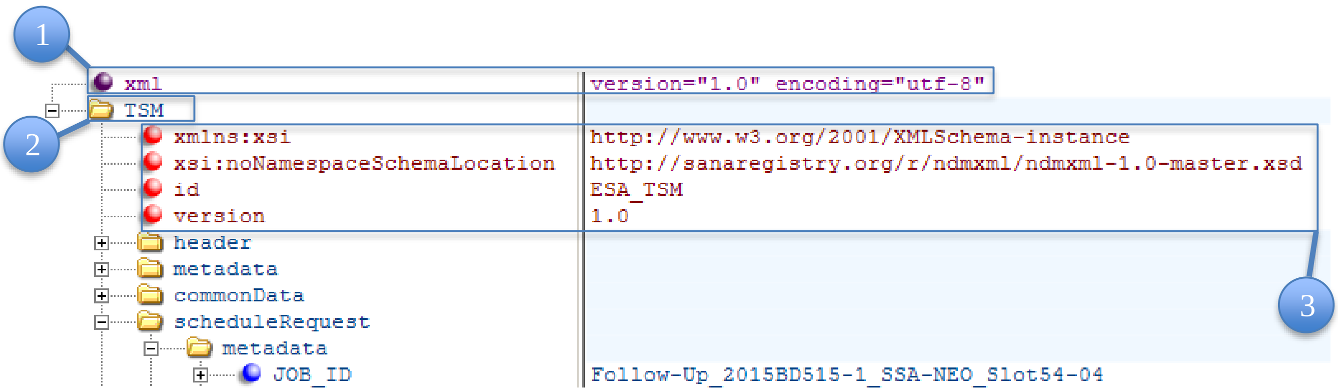


Figure 15 XML document declaration and root element attributes

1	XML declaration. Defines the XML version and the character encoding.
2	Root element of the document (i.e. defining: "this is a TSM document")
3	Root element attributes. Each has the following functions: xmlns:xsi - defines the namespace used in the document. The URL does actually point to the website, but is the name of the namespace. xsi:noNameSpaceSchemaLocation - Defines the location of the XML schema (the grammar to be used for validation) for elements that do not belong to any namespace (basically all elements in a TSM) id - Identification code for the document code. Shall always be "ESA_TSM". version - Identifies the version of the TSM data format that is used throughout the document.

Header in ASCII code:
```
<?xml version="1.0" encoding="utf-8"?>
 <TSM xsi:noNamespaceSchemaLocation=" http://sanaregistry.org/r/ndmxml/ndmxml-
     1.0-master.xsd" id="ESA_TSM" version="1.0">
```

10.2 Auxiliary Messages

For unrestricted control of the telescope and custom operation, the TSM provides an open string element, the AUXILIARY_MESSAGE. It is primarily foreseen to providing additional data that is not foreseen to be transmitted in a TSM. It can, however, also be used for a variety of other applications, such as to provide custom scripts to a local scheduler or to pass telescope specific commands directly through to the control level below the local scheduler / telescope control computer directly interfaced by TSMs.

AUXILIARY_MESSAGEs can generally be added at any location in a TSM and may contain any Unicode characters. The characters &, <, >, “, and ‘ need to be escaped with the following entities: & with & , < with < , > with > , “ with " , and ‘ with ' .

At which locations in a TSM hierarchy AUXILIARY_MESSAGEs can be placed and when and how they are read out must be determined by the specific telescope/observatory.

An observatory may, for example, allow advanced shutter settings to be specified in observatory-specific code (e.g. Keyword-Value Notation, observatory-specific commands) and included in an AUXILIARY_MESSAGE to be place in a shutter segment of a TSM. Or it might allow the specification of an observation strategy different to the supported ones for which the necessary parameters are supplied in an AUXILIARY_MESSAGE within a surveyStrategy segment of a TSM.

10.3 Higher Level logical structures ("sequence" segments)

In order to make it easier to define more complex observational sequences and to increase the efficiency of the data format, higher level logical structures are supported by TSM. They should make it possible to define loops, sequences with certain settings, etc. In the current version of the format, this is supported via "sequence" segments that can be added as first level elements in a "request" mode TSM. While further versions may offer more possibilities, other structures currently need to be transmitted via auxiliaryMessages.
All higher level logical structures should make use of the observation blocks "command" or "scheduleRequest" as basic elements of an observation.

"sequence" segments allow the simple repetition of observations, but also the construction of observation sequences with different settings, e.g. filters. The included elements are listed below.

Keyword	Type	Description	Unit	Mandatory
NUMBER_OF_REPETITIONS	integer	Indicates how often the included scheduleRequest(s) shall be repeated.	-	Yes
blockIDExtensions segment		Can be used to define how BLOCK_IDs of scheduleRequests to be repeated within the sequence shall be extended. If provided, as many EXTENSION elements need to be defined as repetitions should be carried out. If this element is not included, the scheduler should use a default extension to vary the BLOCK_IDs. (e.g. "_x" with x being a letter starting at "a" and increasing in alphabetical order).	-	No
EXTENSION	string	Extension string for the BLOCK_ID to be used on the first execution of an included scheduleRequest	-	No
EXTENSION	string	Extension string for the BLOCK_ID to be used on the second execution of an included scheduleRequest	-	No
imageNameExtensions segment		Can be used to define how image names of scheduleRequests to be repeated within the sequence shall be extended. If provided, as many EXTENSION elements need to be defined as repetitions should be carried out. If this element is not included, the scheduler should use a default extension to vary the image names.	-	No
EXTENSION	string	Extension string for the NAME in imageData to be used on the first execution of an included scheduleRequest	-	No

EXTENSION	string	Extension string for the NAME in imageData to be used on the second execution of an included scheduleRequest	-	No
REPEAT_ALL	boolean	Indicates whether in case the observation of one of the fails, all linked blocks shall be executed again/whether the success of one block depends on the success of all other linked blocks. If not listed, default state is “false”.		
changes segment		Within the changes segment, sequences of lowest-level elements can be provided that should be used in the repetitions of the included scheduleRequest. The number of instances of a lowest-level element must match the NUMBER_OF_REPETITIONS. The instance provided first will be used for the first execution, the instance provided second for the second execution, and so on. The elements need to be provided in their correct hierarchy		No
camera segment				No
device segment				No
spectrograph segment				No
imageData segment				No
target segment				No
surveyStrategy segment				No
constraints segment				No
calibrationObservation segment				No
exposure segment				No
observation segment				No
scheduleRequest segment		The scheduleRequest that shall be repeated. A sequence segment may contain several scheduleRequests.		Yes

The following example illustrates the use of a sequence segment to request the observation of the same target with three different filters and adjusted exposure times for each filter.

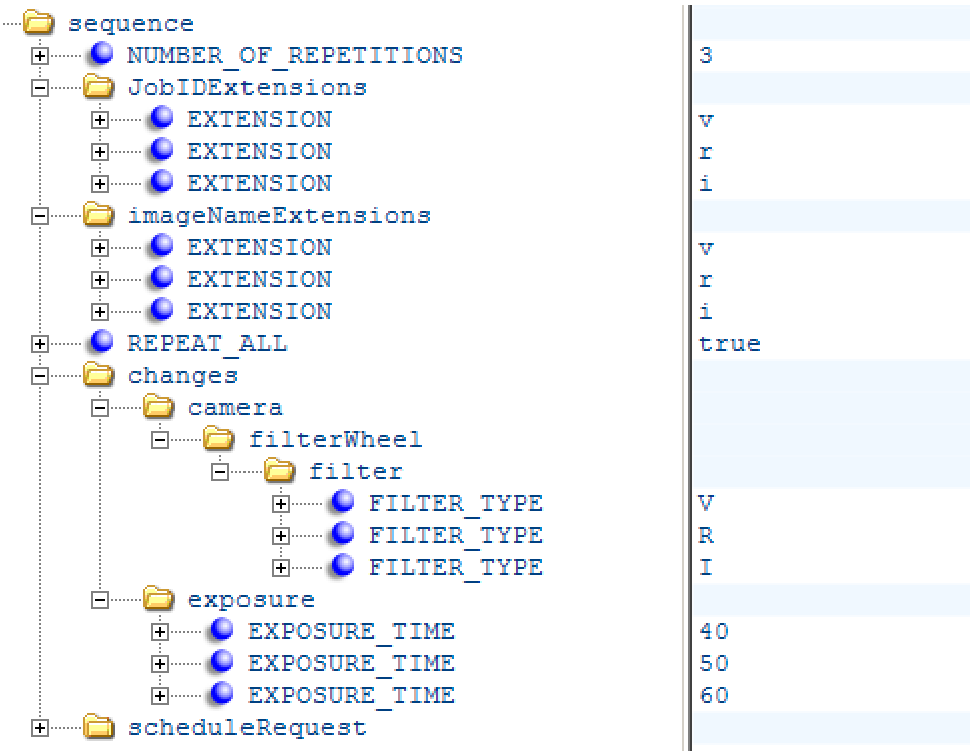


Figure 16: Example of a sequence segment

10.4 Handling of FITS header keywords

10.4.1 General expected behavior in regard to writing to FITS headers

FITS header keywords included in a fitsHeader segment shall generally be written to the resulting image file's FITS header as specified in the TSM. Empty keywords shall be omitted.
The telescope/scheduler creating the image file shall always have priority of overwriting requested keyword values in order to prevent accidental predefinition of e.g. wrong or changed observation times.
The tables in the following section provide an overview of keywords defined in and required by the FITS standard and additional keywords used or required in the context of ESA's SSA Programme. The tables are meant to provide an overview, for the authoritative rules, [RD16] should be consulted.

10.4.2 FITS header keywords proposed to be supported in the context of ESA SSA

Keywords required according to the FITS standard are marked with *.
Keywords additionally required in the context of ESA's SSA-NEO segment are marked with ** or listed in the subsequent table.

Keywords defined in the FITS standard [RD15]:

(blank)	CROTAn	EQUINOX**	NAXISn*	TBCOLn	TUNITn
AUTHOR	CRPIXn	EXTEND*[8]	OBJECT**	TDIMn	TZEROn
BITPIX*	CRVALn	EXTLEVEL	OBSERVER**	TDISPn	XTENSION
BLANK	CTYPEn	EXTNAME	ORIGIN	TELESCOP**	
BLOCKED	DATAMAX	EXTVER	PCOUNT	TFIELDS	
BSCALE*	DATAMIN	GCOUNT	PSCALn	TFORMn	
BUNIT	DATE**	GROUPS	PTYPEn	THEAP	
BZERO*	DATE-OBS**[9]	HISTORY**[10]	PZEROn	TNULLn	
CDELTn	END*	INSTRUME**	REFERENC	TSCALn	
COMMENT	EPOCH	NAXIS*	SIMPLE*	TTYPEn	

[8] Only obligatory if the FITS file contains an extension
[9] If DATE-OBS is given in the complete CCSDS format, DATE or TIME-OBS are not needed.
[10] This keyword is only required if the image has indeed been flat-corrected or bias-corrected. Alternatively, the keyword PROCSTAT= could be used, with the values 'Bias-subtracted' or 'Bias-processed'; 'Dark-subtracted' or 'Dark-processed'; 'Flat-divided' or 'Divided by flat' or 'Flat-processed' or a combination thereof (e.g. PROCSTAT= 'Bias-processed, Dark-processed, Flat-processed').

Additional keywords required in the ESA SSA-NEO segment [RD16]:

APERTUR	DECTRACK	EXPTIME	GUIDING	RA	TRACKING
APTDIA[11]	EGAIN[12]	FILTER	NREFLECT	RATRACK	TIME-OBS
CCD-TEMP[13]	ELEVATIO	FLENGTH[14]	OBSCODE	SCALE	UTC-DATE
CHIPTEMP	EPOMJD	FOCALLEN	OBSTRUC	SITELONG	XBINNING
DEC	EXPOSURE	GAIN	OBSTYPE	SITELAT	YBINNING

Additional keywords used in OGS Images:

STATION	CREATOR	VERSION	NTAXIS	MGAIN	EPSYSTEM
RCOORDTYP	COORDTYP	CHIPORI	READMODE	CONTROL	REDUCTIO
REDCTFLG	ROCH	DRIFTRAT	SMEARLIN	SMEARCIYC	MOUNTMOD
TELETEMP	EPOCHTYP	TAXIS-R1	TAXIS-R2	TAXIS-V1	TAXIS-V2
TAXIS1	TAXIS2	FOCUSPOS	OBSTYP	SHUTTER	OBSNAME
CAMPAIGN	SESSION	SERIENAM	SERIENUM	SERIETR	
PIXELRAT	SENSITIV	TELPOS	CHIP-X	CHIP-Y	
XOFFSET	YOFFSET	CGAIN	OVSCX	OVSCY	
MRDNOISE	RDNOISE	O_BZERO	TIME	NCHIP	

[11] Either APTDIA or APERTURE must be given. Note that the first is the diameter, the second the area.
[12] Either GAIN or EGAIN is required.
[13] Either CCD-TEMP or CHIPTEMP is required.
[14] Either FLENGTH or FOCALLEN is to be used.

10.5 Survey Strategy Types and Related Parameter Requirements

10.5.1 Description of Survey Strategies

The survey strategies for which direct parameters are supported by this TSM proposal represent the standard survey strategies as used specifically in ESA's SSA Programme and for NEO and space surveillance and tracking surveys in general. The survey strategies are described in detail in [RD17], however, the parameters used to describe the survey strategies differ in details. Survey strategy type 1 represents a strategy as used for observations of objects in geosynchronous orbits that makes use of the characteristic that these objects pass the same right ascension once per day. Survey strategy type 2 represents a strategy used for observing primarily objects in medium Earth orbits, usually with the survey fields located at relatively low absolute declination values. Survey strategy type 3 describes strategies that are used for NEO surveys. The following images shall clarify both the strategies as well as the definitions of the parameters used for each strategy. The following sections further indicate which parameters are mandatory and optional for each respective survey strategy type.

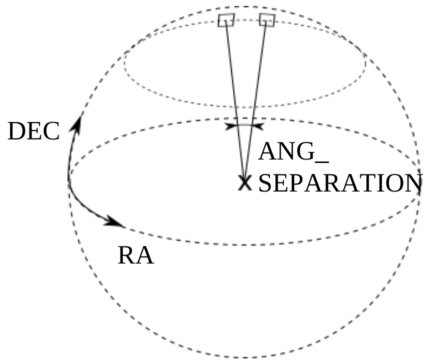
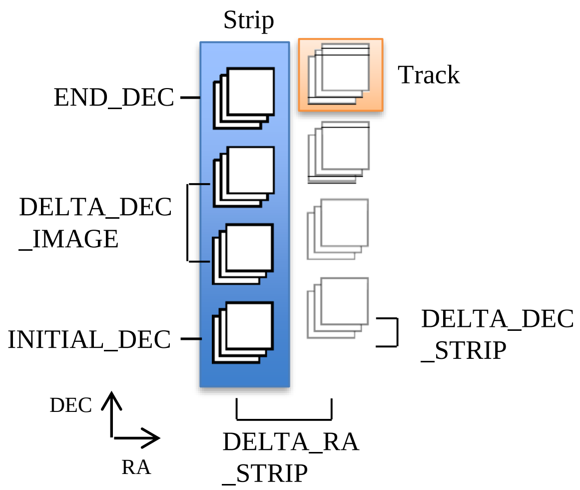


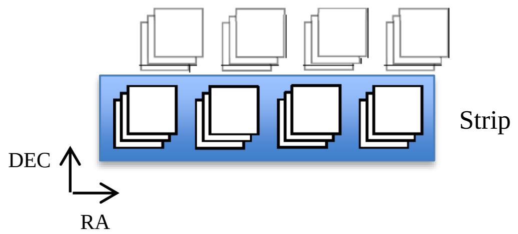
Figure 17: Visualization of the ANG_SEPARATION parameters in an RA-DEC coordinate system

The optional elements ANG_SEPARATION_IMAGE and ANG_SEPARATION_STRIP may be used to replace DELTA_RA_IMAGE and DELTA_RA_STRIP respectively. They describe the requested angular separation between the centers of adjacent fields of view as seen from the telescope, without taking into account a change in declination between two images. The telescope will thus take into account that the difference in RA required to reach the same angular separation is a function of the declination, scaling roughly with 1/cos(DEC) (see also Figure 17).

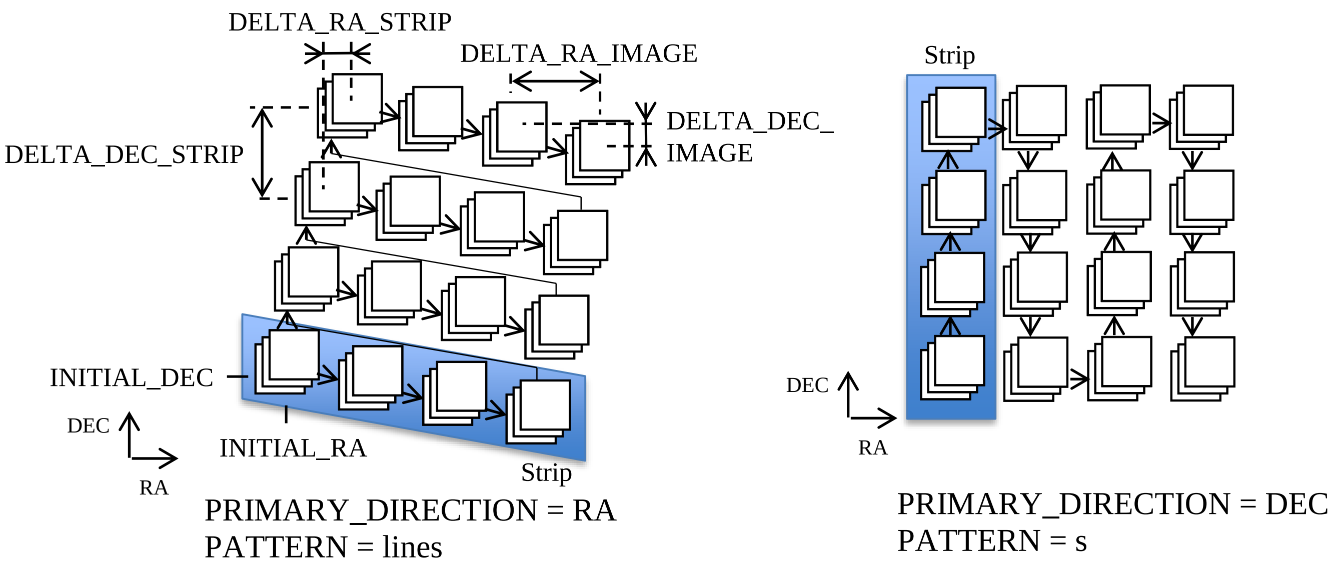
Survey Strategy Type 1



Survey Strategy Type 2



Survey Strategy Type 3



10.5.1 Parameter Requirements for Survey Strategy Type 1 (vertical strip)

Mandatory	Optional
IMAGES_PER_TRACK	DELTA_RA_STRIP
IMAGES_PER_STRIP	DELTA_DECSTRIP
INITIAL_RA	TIME_TRACK_IMAGES
INITIAL_DEC	TIME_CONSECUTIVE_STRIPS
DELTA_DEC_IMAGE	ANG_SEPARATION_STRIP
ANTI_SUN_OFFSET	
NUMBER_OF_STRIPS	
REFERENCE_FRAME	

10.5.2 Parameter Requirements for Survey Strategy Type 2 (horizontal strip)

Mandatory	Optional
IMAGES_PER_TRACK	DELTA_RA_STRIP
IMAGES_PER_STRIP	DELTA_DEC_STRIP
INITIAL_RA	TIME_TRACK_IMAGES
INITIAL_DEC	TIME_CONSECUTIVE_STRIPS
DELTA_RA_IMAGE	ANG_SEPARATION_IMAGE
NUMBER_OF_STRIPS	
REFERENCE_FRAME	

10.5.3 Parameter Requirements for Survey Strategy Type 3 (free mosaic)

Mandatory	Optional
IMAGES_PER_TRACK	DELTA_RA_STRIP
IMAGES_PER_STRIP	DELTA_DEC_STRIP
INITIAL_RA	TIME_TRACK_IMAGES
INITIAL_DEC	TIME_CONSECUTIVE_STRIPS
DELTA_RA_IMAGE	PATTERN
DELTA_DEC_IMAGE	ANG_SEPARATION_IMAGE
NUMBER_OF_STRIPS	ANG_SEPARATION_STRIP
PRIMARY_DIRECTION	
REFERENCE_FRAME	

10.6 Handling of Filter Requests

The TSM offers two options to specify filters to be used. The preferred option is by providing the telescope-specific name identifier/name of a filter available and installed on a specific telescope in the NAME keyword. In case of submitting to a network, where telescopes may have similar but differently named filters, or if the internal names of the filters are not known for another reason, it is also possible to provide the type of filter to be used in the FILTER_TYPE element. This element shall also be used as a fallback, if a NAME is provided, but no filter of this name is available at the telescope.

It is recommended that telescope operators using TSMs assign each of their filters a FILTER_TYPE value from the recommended list, if the filter falls into the respective category. The list values thereby should be understood as broad categories of filters rather than very specific ones. If very specific filters shall be chosen, this should be done via the NAME element. Recommended FILTER_TYPE values are the following (λ0 stands for the center wavelength, Δλ for the bandwidth):

clear	configuration that merely improves visible imagery or does nothing, e.g. no filter, clear filter, IR cut.	K	λ0 ~ 2190 nm, Δλ ~ 390 nm
U	λ0 ~ 365 nm, Δλ ~ 66 nm	L	λ0 ~ 3450 nm, Δλ ~ 472 nm
B	λ0 ~ 445 nm, Δλ ~ 94 nm	M	λ0 ~ 4750 nm, Δλ ~ 460 nm
V	λ0 ~ 551 nm, Δλ ~ 88 nm	N	λ0 ~ 10500 nm, Δλ ~ 2500 nm
R	λ0 ~ 658 nm, Δλ ~ 138 nm	Q	λ0 ~ 21000 nm, Δλ ~ 5800 nm
I	λ0 ~ 806 nm, Δλ ~ 149 nm	VR	sometimes referred to as "solar", λ0 ~ 630 nm, Δλ ~ 333 nm
Z	λ0 ~ 900 nm, Δλ ~ 95 nm	w	wide passband, basically VRI i.e. λ0 ~ 709 nm, Δλ ~ 492 nm
Y	λ0 ~ 365 nm, Δλ ~ 66 nm	RI	λ0 ~ 738 nm, Δλ ~ 435 nm
J	λ0 ~ 1020 nm, Δλ ~ 120 nm	*wavelength*	Specific wavelength for a narrowband filter. See below.
H	λ0 ~ 1630 nm, Δλ ~ 307 nm		

Specifying narrowband filter types (*wavelength* value)

If a narrowband filter shall be used but the filter's name on the telescope/observatory is not known (or the specific telescope/observatory is not known, as may be the case when submitting to a network), it is recommended to specify the desired filter by supplying the desired center wavelength in nm as an integer in the FILTER_TYPE element. The telescope/observatory on which the observation is carried out should then choose an available narrowband filter with the closest center wavelength to the requested center wavelength within an interval of +/- 5 nm around the requested center wavelength. If no such filter is available, a warning should be returned and the observation should not be carried out.

It is recommended to consider filters with a Full Width Half Maximum of 20 nm and less as narrowband filters.