# Project Management for Scientists 2017

# Lecture 4: Science Requirements

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# Introduction

- Requirements:
  - Systematic translation of scientific idea into requirements
  - Basis for accurate budget and schedule estimates
  - Basis for verifying performance of final product
  - Describe ideal outcome of project
- Uncertainty in requirements -> uncertainty in cost and schedule -> uncertain success
- Many projects fail due to vague and/or undocumented requirements
- Requirements change -> project changes

# Requirements Hierarchy

Top -> Down, Big -> Small, What -> How

1. Science rational
2. Science objectives
3. Measurement objectives
4. Science requirements
5. Technical Requirements
6. Design Requirements
7. …

# Science Objectives

- Science vision and strategy explained in detail by science rationale
- Science rationale leads to science objectives or science drivers
  - I would like to understand …
  - We need to observe, measure, test, …
  - This is how well I need to observe, measure, test …

# Science Objectives Examples: SOLIS

The long-term studies of the most important astronomical object to humanity will provide the fundamental data to help answer the following questions:

- What causes the solar cycle?
- How is energy stored and released in the solar atmosphere?
- How does the solar radiative and non-radiative output vary?

# Measurement Objectives

- Measurements required to achieve science vision
- In astronomy: key observations
- Example (SOLIS):
  - Line-of-sight component of the photospheric magnetic field: averaged over 2 Mm squared projected area, sensitivity 1G, zero point stable to 0.1G, time for a full disk map: 15 minutes, shorter for smaller areas.
  - Transverse component of the photospheric magnetic field. Same parameters as line-of-sight component except sensitivity 20G.
  - Morphology of coronal magnetic fields from limb observations of coronal emission lines. Angular resolution about 3 arcsec, noise level $<10^{-4}$ of the disk brightness.

# Science Case Example: METIS@ELT

- Proto-planetary disks and the formation of planets
  - breakthrough science:
    1. Reveal the spatial distribution of gas and dust on ca. 1 AU scales
    2. Allow kinematic and spatial studies of disk dynamics
    3. Permit spatio-chemical analysis of gas and dust-phase disk constituents

# Measurement Requirements: METIS@ELT

Requirements derived from Protoplanetary Disk science case

| | |
|---|---|
| Spectral range | L, M & N (goal Q) |
| Resolving power | spectral resolution to 100,000 & IFU |
| AO | Diffraction limited performance |
| Photometric stability | Spectro-astrometry |
| Coronagraph | Yes |

# Science Requirements

- Merge requirements from individual science cases to fulfill science vision and strategy
- Must be traceable back to science cases
- Project scientist is responsible for science requirements
- If requirement too difficult to formulate, use examples of how things will work (use cases)
- Project team may need to interview scientists

# Science Requirement Example: SOLIS

***SR.1 Science goals***

**Need:1** **Priority:1** **Source:** *SOLIS, Proposal to NSF dated 12 February 1997*

SOLIS will produce observations to understand (1) the causes of the solar activity cycle, (2) storage and explosive release of energy, and (3) causes of radiative variability.

***SR.2 25-year lifetime***

**Need:1** **Priority:1** **Source:** *SOLIS, Proposal to NSF dated 12 February 1997*

Duration of the stream of regular observations will be at least 25 years.

***SR.3 Relation to other activities***

**Need:1** **Priority:2** **Source:** *SOLIS, Proposal to NSF dated 12 February 1997*

SOLIS observations will be integrated into the National Space Weather Program, operational needs of NOAA/SEL, support of NASA mission, and collaboration with other organizations.

***SR.4 Community access***

**Need:1** **Priority:2** **Source:** *SOLIS, Proposal to NSF dated 12 February 1997*

SOLIS observational capabilities will be made available to as many qualified users as possible.

# Science Requirement Example: METIS

| Level | Reqt-ID | Title | Requirement | Comments |
|---|---|---|---|---|
| 2 | SC-0201 | Wavelength coverage | The METIS imager shall cover the LM band and the N band. | The objective is given in the summary table. |
| 2 | SC-0202 | Pixel sampling | The METIS imager shall provide Nyquist-Shannon sampling of the PSF at 3.5µm and 7µm. | The objective for the chosen wavelengths is to provide critical sampling over most of the LM band. |
| 2 | SC-0203 | Field of view | METIS shall provide an imaging field of view of at least 15".15". The aspect ratio of the field should be close to unity. | The objective is to provide critically sampled, diffraction limited (AO-corrected) images over a field size that is sufficient for most individual targets and allow for on-chip chopping. |

# JWST Science Requirements Traceability Matrix

| | First Light | Assembly of Galaxies | Birth of Stars and Protostars | Planetary Systems and the Origins of Life | Science Requirements |
|---|---|---|---|---|---|
| **NIRCam** | | | | | |
| Broad-band | ✓ | ✓ | ✓ | ✓ | SR-1, SR-2, SR-4, SR-5 |
| Sensitivity | ✓ | ✓ | ✓ | ✓ | SR-10, SR-16, SR-17 |
| Photometric Accuracy | ✓ | ✓ | ✓ | ✓ | SR-20 |
| FOV | ✓ | ✓ | ✓ | ✓ | SR-21 |
| PSF | ✓ | ✓ | | | SR-11, SR-22, SR-14, SR-15 |
| PSF $\lambda$<1 μm | ✓ | ✓ | ✓ | ✓ | SR-13 |
| Coronagraphy | | | ✓ | ✓ | SR-3 |
| **NIRSpec** | | | | | |
| Multi-obj FOV | ✓ | ✓ | ✓ | ✓ | SR-7, SR-21 |
| R = 100 | ✓ | ✓ | ✓ | | SR-4, SR-6 |
| R = 1000 | ✓ | ✓ | ✓ | ✓ | SR-4, SR-6 |
| R = 3000 | | ✓ | ✓ | ✓ | SR-4, SR-6 |
| Sensitivity | ✓ | ✓ | ✓ | ✓ | SR-10, SR-16 |
| Photometric Accuracy | ✓ | ✓ | ✓ | ✓ | SR-20 |
| PSF | ✓ | ✓ | | | SR-11, SR-22, SR-14, SR-15 |
| PSF $\lambda$<1 μm | ✓ | ✓ | ✓ | ✓ | SR-13 |
| High Contrast | | | ✓ | ✓ | |

# Requirement Requirements

- Must be organized and traceable
- Must be verifiable
- Need to have scope flexibility:
  - Prioritized
  - Information on need (what if not fulfilled)
  - Requirements (“must”) and goals (“should”)
- Prepare de-scope options
- Need flexibility in fulfilling science requirements
  - Watch out for ‘over’-specifying
  - Do not limit design, implementation

# Requirement Template

- **Identifier:** Unique enumeration
- **Title:** Few, descriptive words
- **Need**: Essential requirements marked ‘1’. Non-essential requirements marked ‘2’, ‘3’ in descending level of importance
- **Priority**: Priority for completion. Requirements with priority 1 will be completed first, followed by priorities of 2, 3, …
- **Source**: Origin of requirement can be found in document referenced by this entry
- **Description**: Requirement itself

Courtesy B.Goodrich

# Requirements Checklist

Check for

- ❑ clear, unambiguous requirements
- ❑ verifiable requirements
- ❑ consistency among requirements
- ❑ gaps in requirements
- ❑ requirements from beyond project lifetime
- ❑ unnecessary requirements (design restrictions)
- ❑ traceable requirements (identification of underlying assumptions)
- ❑ unique identifier for every requirements

# Good or bad?

- SR-1:  JWST shall be capable of making astronomical observations at wavelengths from 0.6 to 27 micrometers.
- SR-3: JWST shall have coronagraphic imaging capability over the wavelength ranges 2 to 27 micrometers.
- SR-10: JWST shall have a primary mirror whose unobscured light collecting area is no less than 25 square meters.
- SR-27: The Observatory shall be capable of observing at least 35% of the celestial sphere at any time.

# Good or bad?

- SR-32: The JWST science mission lifetime, after commissioning, shall be a minimum of 5 years.
- As a goal, the JWST science mission lifetime shall be 10 years. In support of this goal, JWST shall meet the following requirement:
  SR-33: Propellant shall be sized for 10 years of operation after launch.

# Good or bad?

- List of priority ‘A’ products
  - SR 3.1.1 OMI shall retrieve the Earth radiance spectrum.
  - SR 3.1.2 OMI shall retrieve the solar irradiance spectrum.
- List of priority ‘B’ products
  - SR 3.1.15 OMI shall be able to retrieve the total $SO_2$ column.
  - SR 3.1.16 OMI shall be able to retrieve the total BrO column.

# Good or Bad?

- SR 3.2.7.1 Near Real Time (NRT) products shall be available within 3 hours after observation.
- SR 3.2.8.1 The OMI data (gathered above Europe and Scandinavia) shall be downloaded to the FMI ground station at Sodankylä (Finland) on one pass per day.
- The accuracy of the irradiance product shall be less than or equal to 2 %.

# Other Requirements

- Functional requirements: specify a function that a system or system component must be capable of performing
- Performance requirements
- Interface requirements
- Operational requirements
- Resource requirements
- Verification requirements
- Acceptance testing requirements
- Documentation requirements
- Security, Portability, Reliability, Maintainability, Safety requirements

# Science Requirements Example: EPOL

| Entry | Content |
|---|---|
| EPOL Reqt ID | EPOL-S001 |
| Parameter | Giant planets |
| Requirement Description | Detection and characterization of mature gas giants at orbital distances between ~5 and 15 AU in the solar neighbourhood (< ~20 pc) |
| Priority/Clarification | High priority |
| Upper Link | AD1 4-2 |
| Upper Link | |
| Requirement document | E-SPE-ESO-556-0194 issue 2 |
| Verification Method | |

# Functional Requirements Example: EPOL

| Entry | Content |
|---|---|
| EPOL Reqt ID | EPOL-0001 |
| Parameter | Contrast I band |
| Requirement Description | 10h, reference conditions etc. for mature gas giants (science case 2) contrast 2·10-9 (goal 1·10-9) at 100 mas, and 10-9 (goal: 4·10-10) at 300 mas |
| Priority/Clarification | AI missing simultaneous wavelength range, missing polarization state of planet system. Need to get a reference where numbers come from |
| Upper Link | AD1 5-6b |
| Upper Link | EPOL-S001 |
| Requirement document | E-SPE-ESO-556-0194 issue 2 |
| Verification Method | |

# Optical Design Requirements Example: EPOL

| Entry | Content |
|---|---|
| EPOL Reqt ID | EPOL-0206 |
| Parameter | Image quality over full field |
| Requirement Description | Optical WFE < 75 nm rms (goal 50 nm rms) |
| Priority/Clarification | The image quality degradation due to optics over the field should remain small as compared to atmospheric anisoplanatism. |
| Upper Link | RD2 8.3 A |
| Upper Link | EPOL-0001, EPOL-0002 |
| Requirement document | VLT-SPE-SPH-14690-0083 issue 3 |
| Verification Method | |

# Deliverables

- What the project will produce
- Defines boundaries of the project
- Focuses team on project outcome
- Intermediate deliverables are used to manage project
- Final deliverables define project outcome

# Deliverables Example

- 7101 Differential polarimetry trade-off study
- 7102 Fast modulator in front of AO system: requirements on wave front control
- 7201 Differential polarimetry system design and analysis
- 7301 Models for differential aberrations, and temporal wave front distortions of polarization modulators
- 7302 Measurements for the differential aberrations, and temporal wave front distortions of selected polarization modulators
- 7303 Wave front control with polarization modulation test report