National Aeronautics and
Space Administration

EXPLORESCIENCE

Writing Level 1 Requirements
DYNAMIC Phase A Kick-off Meeting

Dr. Jared Leisner
Heliophysics Division
Science Mission Directorate

Level 1 and 2 Requirements

- Level 1 and 2 requirements are defined in the DYNAMIC C&R [C&R §E.1]
  - Level 1 requirements define the key scientific determinations and/or results that would represent completion of the investigation science objectives.
  - Level 2 requirements define the first level of project-specific mission implementation requirements.

- Level 1 and 2 requirements are addressed in Factor B-8 [Req. CS-21]
  - Evaluators will be instructed to use the standards written in the C&R
  - Evaluators will have access to this presentation

- Examples of Level 1 requirements are being posted in the Program Library
  - Psyche (PSD), TESS (APD)
    - Note: For TESS, look to the key scientific determinations/results in the rationales

Goals and Objectives

- Projects are formulated starting with Goals and Objectives
  - *Goal:* A broad scientific effort that is part of a larger strategy to address a program's objectives. An investigation will make progress towards the project's Goals.
  - *Objective:* A focused scientific effort that is part of a larger strategy to address a project Goal. An Objective must be achieved by an investigation.

- Can think of putting an Objective into one of three rough categories (*my terms*):
  - Characterization: You know enough to design a mission to study a system at a high-level.
    - Voyager characterized Jupiter's atmospheric winds (number of bands, speed of each band).
  - Hypothesis-testing: You have specific hypotheses that a mission can be designed to resolve.
    - GEP [decadal survey concept] would determine whether feedback from buried accreting black holes could have caused the decline of luminosity density from star formation in the last half of the Universe's history. *[quote from concept study]*
  - Analytic: You have specific knowledge gaps about an understood (to some level) system that a mission can be designed to fill.
    - THEMIS determined the relative timing of substorm onset in the auroral zone and in the magnetotail.

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Uses progress-based verbs like "understand"

Uses completion-based verbs like "determine"

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Requirement Levels

Requirements Level	Mission Level
Level 1	**Program**
Level 2	Project
Level 3	Instrument, Mission System
Level 4	Subsystems

These are requirements, so they flow up and down:
- Level N Requirement(s) decompose down to Level (N+1) Requirements
- Level N Requirements deliver a product up Level (N-1) Requirement(s)

These are requirements, so they must be validated and verified [NASA Sys. Eng. Hdbk]:
- Validate: The product would complete the intended purpose in the intended environment.
- Verify: The product met each "shall" statement as proven though performance of a test, analysis, inspection, and/or demonstration.

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As there is no higher level, Level 1 Requirements can only deliver a product to the program (to NASA). And the product promised to NASA is *completion of the Science Objectives*.

Therefore, Level 1 Requirements are the scientific determinations and/or results that represent completion of each Science Objective.

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These are requirements, so they flow up and down:
- Level 1 Requirement(s) decompose down to **mission measurement capabilities**
- Level 1 Requirements **represent completion of the Science Objectives**

These are requirements, so they must be validated and verified [NASA Sys. Eng. Hdbk]:
- Validate: The investigation would complete **its Science Objectives during prime science operations**.
- Verify: The investigation **completed its Science Objectives** as proven though performance of a test, analysis, inspection, and/or demonstration.

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Remember that Level 2 Reqs must be met through prime science ops.

Therefore, validation and verification of the Level Reqs *must use* the full mission data set.

The link between Level 1 and Level 2 is the research plan.

Requirement Levels

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Level 1 Requirements are the scientific determinations and/or results that are necessary for completion of each Science Objective.
- They are agnostic to mission implementation details, but mission implementation details flow up to them.

Example: The [project name] shall determine the average time for [auroral emission] to maximize after the impact of [solar wind structure] with an accuracy of X minutes ([confidence level]).

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Combines multiple measurements for each event!

Multiple events required!

Writing Level 1 Requirements

- How do I determine my Level 1 Requirements?
  - Assume the mission data sets are completed and already archived.
  - Imagine the research paper(s) that uses the archived data sets to complete the Science Objectives. What do the key figures, tables, etc. show? The key scientific determinations and/or results.
    - If a science requirement can't be displayed like that, there might be challenges for validation/verification.
    - A result could reduce to another result, and thus the second does not need to be a requirement.
  - Once they are drafted, they can flow down into Level 2 and lower requirements.
    - Define the trade within and between systems (for example, a Level 1 requirement's accuracy can bound measurement number, cadence, accuracy, and precision)

- A science team will do so much research that quantifying it all will be extremely cumbersome.
  - Level 1 Requirements do not quantify *all* science results to be completed. They quantify the science results that are the main tent poles for the Science Objectives (validation, verification) and that drive mission implementation requirements (flowdown/decomposition).

- My mission data will enable more science than we anticipate right now.
  - NASA expects that. Since you can't anticipate it, it can't be a project requirement. Therefore, it can't be in your Level 1 Requirements.

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Requirement MadLibs!

Level 1 Requirements

- Level 1 Mad Libs: The investigation shall [quantitative scientific-result verb] [aspect of the physical system] [prepositional phrase] [verification parameter(s)].

- Quantitative scientific-result verb
    - All requirements must lead to a pre-registered, quantified scientific result.
    - "Intent-based" verbs are precluded: "study", "investigate", "perform", "survey", "search"
    - "Result-based" verbs are required: "determine", "map"

- Aspect of the physical system

- Verification parameter(s)

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- Quantitative scientific-result verb

- Aspect of the physical system
    - Science Objectives require results about the physical system. (Not just measurements.)
    - Written to be agnostic of the research plan that accomplishes them.
    - The aspects are varied and depend on the particulars of a mission.
    - Because these Level 1s are shown to be met at the end of the mission, they are aggregates. For dynamic systems, time-separated events, etc., Level 1s target characteristics of a statistical distribution (e.g. average, 80th percentile).
        - Ex: rise time of a specific signal after a particular event (e.g. auroral radio emission after CIR impacting the magnetosphere), fraction of a specific energy input partitioned into a specific output (e.g. electron heating in a solar coronal event)

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Level 1 Requirements

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- Quantitative scientific-result verb

- Aspect of the physical system

- Verification parameter(s)
    - The robustness of the results that the project must achieve.
    - Origin of flow down into implementation requirements.
    - Needs to be sufficient to deliver compelling science for NASA's investment. Should not be the best that the implementation can do.
    - Examples: accuracy (space, time, fraction, etc.), confidence level, coverage ("80% of the surface of Planet Acme", "75% of the total energy")

- Many Objectives have more than one Level 1 Requirement. The exact form of the L1s depends on the project-specific Objectives.

Level 1 Requirements

- Level 1 Mad Libs: The investigation shall [quantitative scientific-result verb] [aspect of the physical system] [prepositional phrase] [verification parameter(s)].

- Level 1s can be imagined as coming in one of two forms:
  - Test: The "aspect of the physical system" is a test whether some specific observable configuration of the physical system is fulfilled. Hypothesis- or search-based Objectives may be able to use one or more test requirements.
    - The investigation shall determine whether the abundance of Element X in Astrophysical Structure Y increases with radial distance to a 90% confidence interval.
    - The investigation shall determine whether the average magnetopause reconnection rate increases with Earth's tilt towards the Sun to a 95% confidence interval.
  - Task: The "aspect of the physical system" is a required analysis task to draw scientific conclusions about the physical system. All Objectives can use one or more task requirements.
    - The investigation shall determine Planet Acme's internal magnetic field to degree 2 and order 2 with 10% accuracy.
    - The investigation shall determine the average Auroral Emission X rise time after the impact of Solar Wind Structure Y with an accuracy of 5 minutes.
    - The investigation shall determine the absolute age for Planet Acme's geologic units larger than X by Y km with an accuracy of 5 minutes for at least 80% of the surface.

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Note: All of these Level 1s require multiple measurements. There are no measurement-specific parameters (e.g., precision, integration time, time between observations).

Level 2 Requirements

- Level 2 Mad Libs: The mission shall [quantitative measurement verb] [parameter of the physical system] [prepositional phrase] [verification parameter(s)].

- Level 2 Requirements are the first level of implementation-specific requirements in a mission design.
  - Level 2s describe the data-product requirements for executing the research plan necessary for completing the Level 1s.
  - Level 2s are not the actual observation made by the instrumentation. (For some observables, however, they may be very close. For instance, the vector magnetic field.)
    - Level 2s are still based in the physical system.

- Level 2s have a variability between implementation centers, between projects, and between individuals in leadership positions.
  - Main point is that the Level 1s are based in scientific results and the Level 2s have clear traceability down from the Level 1s.

Questions?