What are requirements and why they are your friends...

A Benevolent Introduction to Requirements

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Outline..

• Learning the lingo through a non-science example.
• What the formal structure of requirements are
• Why they are (or will become) your friends...
I’d like to build a house…

I require a house for people vs. house music, doll houses, cat houses, dog houses…

I require a house for two adults, three children, and two dogs.

Ooh! I can go on and on here! I need a master bedroom, three non-master bedrooms and 2.5 bathrooms. I’m iffy about a pool—if there is money…

Tell me your requirements...

Great! Will be our objective! Tell me more details!

Now we’re talking! Let’s get into the details!

Let’s formalize this..
**What is a requirement?**

They’re not mysterious...

**Requirement:** The *agreed-upon* need, desire, want, capability, capacity, function or demand for instruments, personnel, equipment, facilities, or other resources or services by specified quantities for specific periods of time or at a specified time expressed as a “shall” statement.

**General Language:**

The *[noun]* shall *[quantitative verb]* *[aspect of the physical system]* *[preposition]* *[verification parameter(s)]*. 

More in the interactive section!
## The Language of Requirements...

<table>
<thead>
<tr>
<th>Contains a “shall” in it..</th>
<th>Conveys expectations for what is to be delivered</th>
<th>A way to clearly communicate</th>
</tr>
</thead>
</table>
| Contains one thought per statement | Single interpretation | Active Voice:
“Who” shall “what”? |
| Plain English | No “and/or”s” | Stated Positively
"shall" vs. "shall not" |
Objective: The mission is to build a house.

Level 1: The mission shall build a house for two adults, three children, and two dogs.

Level 2:
- The house shall have one master bedroom.
- The house shall have three non-master bedrooms.
- The house shall have 2.5 bathrooms.

Level 3:
- The master bathroom shall be located on the second floor.
- Master Bedroom Parameters
- Non-Master Bedroom Parameters
- Bathroom Parameters

Level 4:
- The master bathroom shall have one shower.
- The master bathroom shall have one sink.
- The master bathroom shall have one toilet.

The [noun] shall [quantitative verb] [aspect of the physical system] [preposition] [verification parameter(s)].
**Objective:**

Your science objective here

**Level 1:**
The mission shall measure the elevation of at least 90% of the surface with 300 m postings and 10 m height precision.

*Jared will get into detail here!*

**Level 2:**
The project shall acquire single-pass interferometric synthetic aperture radar height measurements (≤10 m accuracy) over ≥95% of Earth’s surface.

Level 2s guide instrument function and performance details
A requirement where the consequence of not meeting the requirement *has significant impact or high sensitivity on the mission’s ability to meet negotiated success criteria*, as assessed by the requirement owner.

If the number of bedrooms is not built, this will impact the ability to meet the level 1 requirement.

**Level 1:** The mission shall build a house for two adults, three children, and two dogs.

A requirement where *compliance is deemed particularly difficult or the likelihood of needing additional resources to meet the requirement is significant*, as assessed by the requirement implementer.

Meeting a requirement, like having the majority of the bedrooms and bathrooms on the second floor in an environment with earthquakes may introduce additional challenges.
I would like to build a house.

Based on the budget and schedule, what can you live without and still achieve your mission?

**DESCOPES: Baseline vs. Threshold?**

- Number of Bedrooms
- Number of Bathrooms
- Number of Floors
- Backyard?
- Basement?
- Patio?
- Pool?
- Garage?
- Energy Source: Electrical/Solar/Geothermal?
- Other?

**Baseline** science requirements are the mission performance requirements necessary to achieve the full science objectives of the mission.

I want it all, I want it all, I want it all...

**Threshold** science requirements are those mission performance requirements necessary to achieve the minimum science acceptable for the investment.

You can't always get what you want, but if you try sometimes, you just might find, you get what you need...

Photo - [https://www.loc.gov/exhibits/british/brit-7.html](https://www.loc.gov/exhibits/british/brit-7.html)
Why should they become my friends?

• The power to define your own path and prove it. You’re not surprised by what you get ("deliverables") or what your deliverables will do (and your stakeholders aren’t either).

• Mission Flexibility When your requirements are written with baselines/thresholds and in a flowed down manner, you’ll have the ability to adapt when situations change (and they will!)

• Verification and Validation Did you do (in a unique and quantitative way) what you said you were setting out to do?

• Clear communication to your team, your stakeholders and the community.

They won’t stifle your creative mojo...
Potential Resources

Movies:
Mr. Blandings Builds His Dream House
The Money Pit

Texts:
The NASA Systems Engineering Handbook
Exploring Requirements Before, Gause and Weinberg
Visualizing Project Management by Forsberg, Mooz and Cotterman
Practical Project Management for Engineers by N. Patel=
Types of Requirements

- **Functional Requirements**: Defines the function that needs to be performed
- **Performance Requirements**: Defines how well the functions need to be performed
- **Interface Requirements**: Define how design elements relate to one another or to other systems
- **Environment Requirements**: Define internal and external environments for flight segment elements
- **Reliability Requirements**: Define probability of failure under specified operating conditions
- **Safety Requirements**: Define human, environmental and asset safety needs
What the initial focus is for most science teams...

- Functional Requirements
- Performance Requirements
- Interface Requirements
- Environment Requirements
- Reliability Requirements
- Safety Requirements

...your engineering colleagues usually get to work the rest, so...

Meme generated at https://fontmeme.com/keep-calm/
BACKUP
Requirements tidbits for after your project gets going.

Requirements are not always static during development

Requirements may need to be added.

Requirements are eventually “frozen”…they won’t change much, if at all, after that...

Requirements can “creep”

Think Antonio Gaudi’s Sagrada Familia...

- Adding in capabilities almost always costs resources: money, schedule, labor
- Do you really need that capability or is it a “desirement” (a desired capability)?
How to write ambiguous requirements.

- And/or in the requirements statement
- Multiple requirements in one sentence.
- Use of vague adjectives/adverbs

Vague phrases, adjectives and adverbs

- About
- Acceptable
- Appropriate
- Applicable
- Average
- Adequate
- Adjustable
- Affordable
- Average
- Optimum
- Normal
- Effective
- Immediate
- Major
- Stable
- Sufficient
- Significant
- Various
- Variable
- Typical
- Necessary
- Possible
- Known
- Approximate
- TBD
- TBR
- Easy
- Safe
- Flexible
- But not limited to
- Be able to
- As appropriate
- Be capable of
Logical Decomposition of Science in a Standard Mission

Applicable to:
- Flybys
- Orbiters (Earth and Planetary)
- In situ missions
- Constellations
- Heliocentric observers
- Sample return missions
- Occultation experiments
The Science “Shalls” Through the Life Cycle

Phase A
(Concept)

Phase-B
(Product Definition)

Phase-C
(Design & Develop)

Phase-D
(Assembly & I/T)

Phase-E
(Operations)

Flight Unit
Assembly/Testing
Science & Instrument Operations Plans

Requirements derived through design iterations

Requirements frozen around PDR

Level 1s Signed

Science & Instrument Operations Plans

Instrument Delivery

Evaluation of Level 1s & Mission Success Criteria

Development of additional Level 1s

Evaluation of Extended Mission L1s

End of Mission

Extended Mission Operations

End of Extended Mission

Requirements derived through design iterations
What the scientists wanted
What the PM envisioned
How the engineer saw it
How the requirements were documented
After PDR...

After CDR...
What the project was going to cost
What the project could afford
What the scientists really needed
Notional System Hierarchy for Requirements

Lisa will talk about this more!
Objective: The mission is to build a house.

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Level 2:
- The house shall have one master bedroom.
- The house shall have three non-master bedrooms.
- The house shall have 2.5 bathrooms.

Level 3:
- The house shall have the master bedroom on the 2nd floor.
- The house shall have one bathroom attached to the master bedroom.
- The house shall have one full non-master bathroom on the second floor.
- The house shall have a half bathroom on the first floor.

Requirement Decomposition

• The process by which requirements defined at one level are allocated or derived into implementable elements.
• It is **NOT** writing the same requirement at the next lower level as a child of a higher level requirement.
• It is **NOT** writing parents for lower level requirements.

*Allocating = Distributing a resource or functional requirement*

*Deriving = Distributing a requirement by analysis or modeling*
Characteristics of Sound Requirements...

- **Unambiguous** - only one interpretation
- **Understandable** – the interpretation of each requirement is clear
- **Correct** - a requirement the system is in fact required to do
- **Concise** - no unnecessary information is included in the requirement
- **Traced** - each requirement is traced to some statement/document
- **Traceable** - each derived requirement must be traceable to an originating requirement
- **Design independent** - does not specify a particular solution or portion of the solution
- **Verifiable** – a finite process can be conducted to check that the requirement has been attained
- **Unique** – requirements are not overlapping or redundant with other requirements
- **Consistent** -(a) internally consistent—no two subsets of requirements conflict and (b) externally-no subset of requirements conflicts with external documents from which the requirement is traced.
- **Comparable** - relative priority of a particular requirement can be compared to other requirements
- **Modifiable** - changes to the requirements can be made easily, consistently, and completely
- **Attainable** - solutions exist within cost/schedule/performance constraints
The “Mary Had a Little Lamb” test...

What is the significance of each word in your requirements?

An Example:
“Mary had a little lamb, whose fleece was white as snow. Everywhere that Mary went the lamb was sure to go. “

Mary **had** a little lamb.  *Used to own? Still owns?*
Mary had a **little** lamb.  *Little in size? Little in age? Little in weight? How little?*
Mary had a little **lamb**.  *A young sheep? A young child? A lamb-orghini?*

Is the requirement free of ambiguities? Unverifiable terms?
Concept of Operations (ConOps/OpsCon)

A description of how the system will be operated during the missions phases in order to meet stakeholder expectations. Timelines and graphics are typical description methods.

Typical ConOps Timeline Elements:

- Launch
- Cruise (and instrument checkout)
- Orbit Insertion/Landing/Flyby
- Instrument Commissioning
- Prime Science Mission
- Extended Science Mission
- Decommissioning/Deorbit/End of Mission activities

Includes command and data transmission sequencing, science operations controls, logistics (resupply
In developing the ConOps, you may make some discoveries....

Requirements Revealed!

New Use Cases!

Changes in ops Sequence!

Requirements Removed!
Figure 4.2-3 The flowdown of requirements