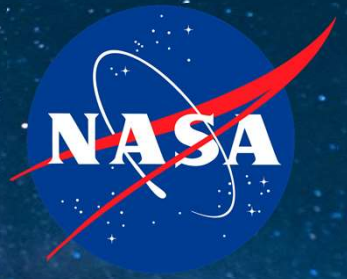
Balloon Payload Workshop

The Design Process



Partner

The Design Process

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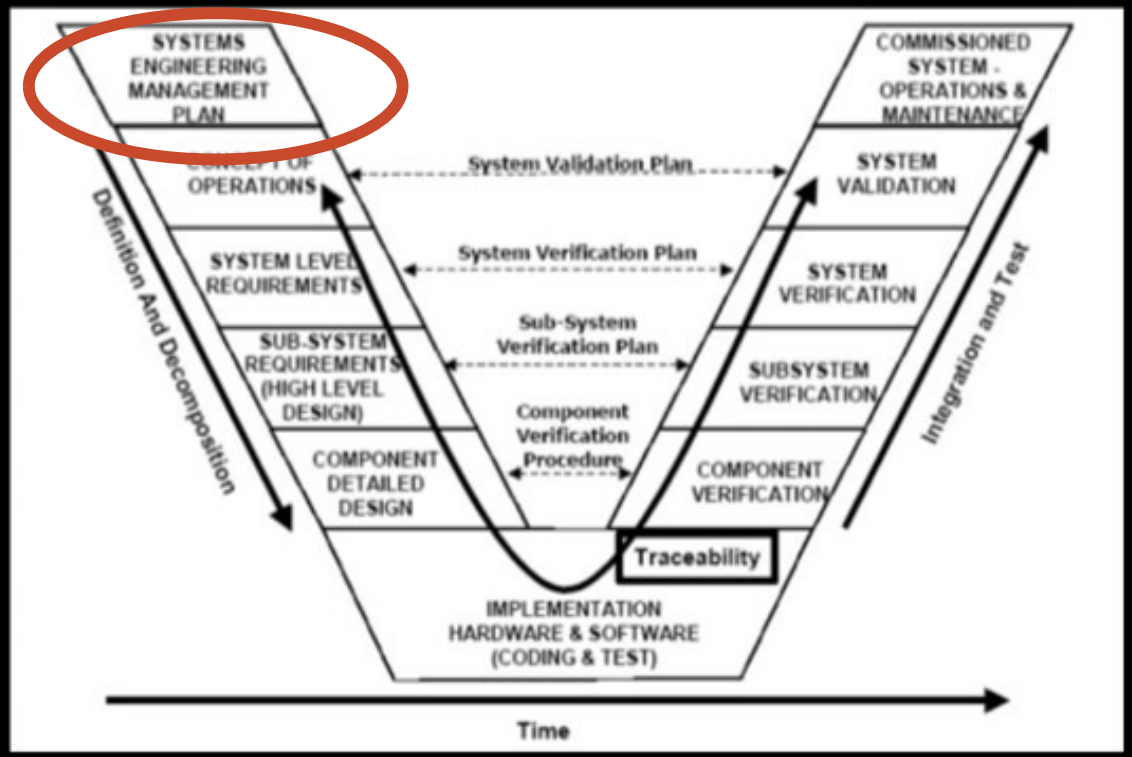
- Systems Approach
- Requirements
- CONOPS
- Design Reviews



Systems Approach

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- Is a systematic, interdisciplinary approach that transforms customer needs into a total system solution
- A framework of interrelated activities that spans Design, Management, and Realization of systems
- Balances customer needs with system capabilities
- Led and organized by Systems Engineers
  - But all functions play a role
- It is the technical “glue” which makes separate design disciplines and subsystems function together to provide an integrated system

Systems Engineering

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- The Design Engineer
  - The specialist's viewpoint
  - Views the system from the inside
  - Concerned with other system elements only as they affect their design task
  - Not necessarily how their system may affect others
- Systems Engineer
  - Views the system from the outside
  - Concerned with the effect of all system elements as they affect overall system design / performance / cost / schedule
  - Concerned no matter where the hole in the boat is

Systems Engineering

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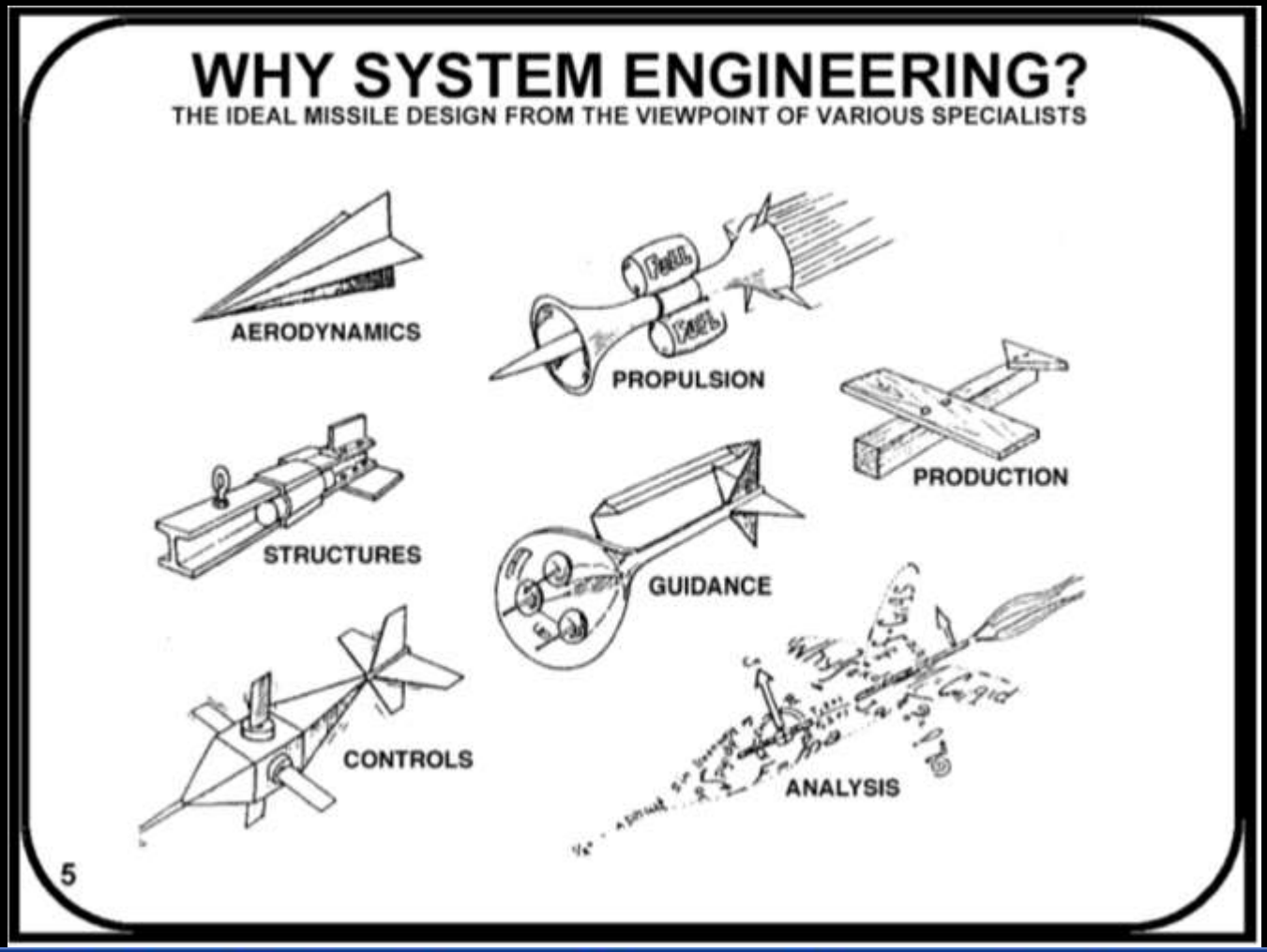

Systems Engineering must focus on the *entire problem:*
optimize the whole, not the parts!

Systems Engineering

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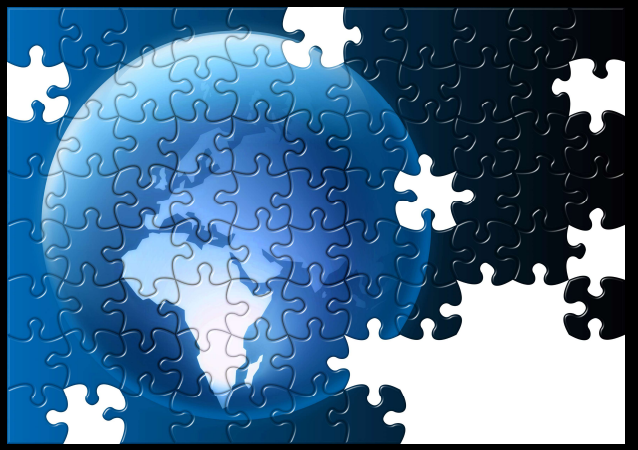
- Art of Systems Engineering
  - Technical Leadership
  - Understanding how all the individual pieces go together to make the big picture



- Science of Systems Engineering
  - Systems Management
  - Managing all the details for every piece of the system and keeping them in synch
    - Cost, Schedule, Performance, and Risk

To be Successful, we must balance both technical leadership and systems management into complete systems engineering

Systems Engineering

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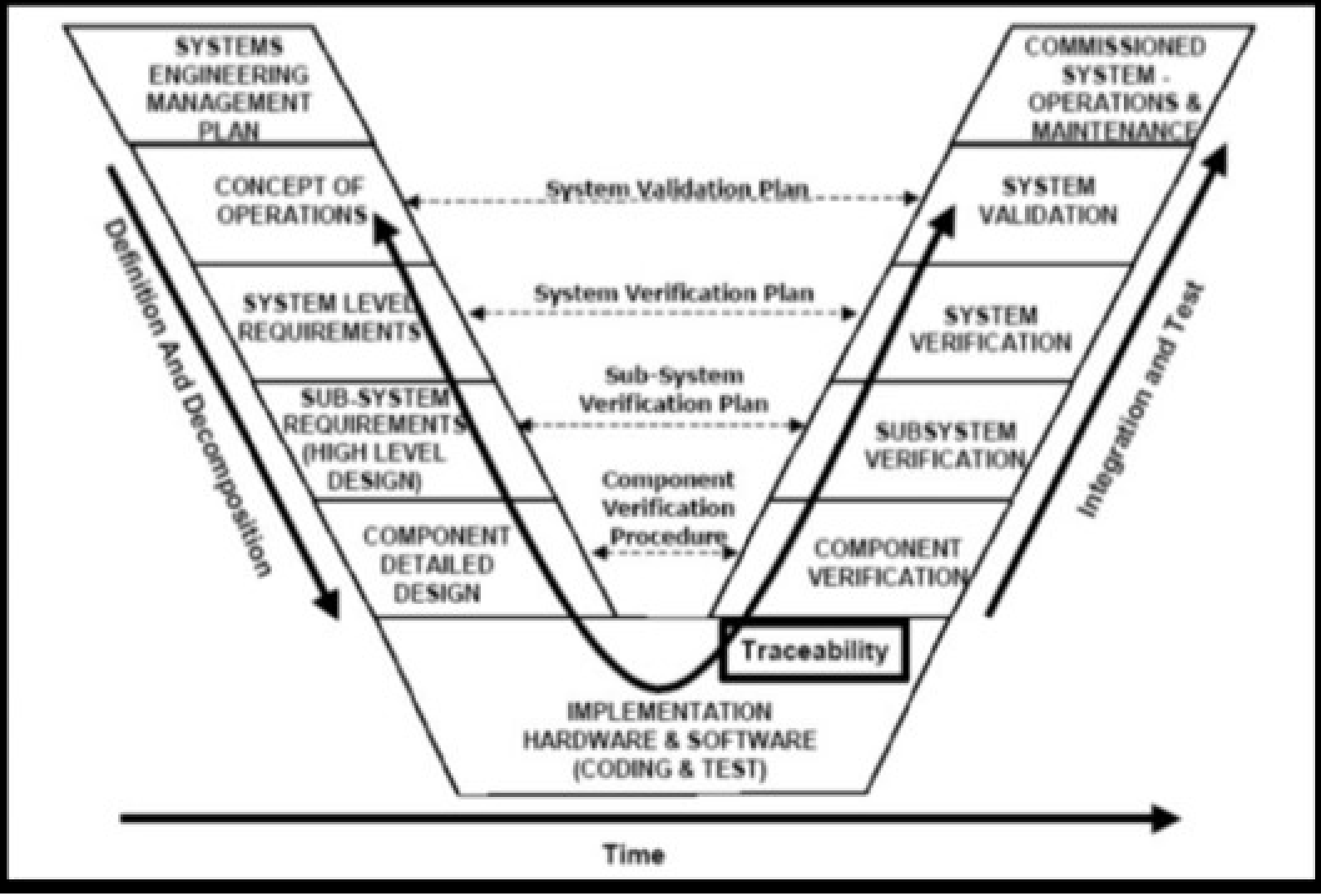
- The "V" Model



The Design Process

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- Where does the Design Process start?
- Every project starts with a question and the project is finding the answers to that question.
- So first ask yourself what question(s) do you want answered?

I Wonder…

The Design Process

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- Mission Statement:
  - What is a mission statement?
  - Why it's important to generate a mission statement.
  - What it is going to do or what you hope to discover.
- Mission Statements are where the requirements for the project will be derived from!

Architecture

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- System Architecture is the overall structure of the program, internal interfaces, and how it interacts with external interfaces
  - System level – Constellation of Satellites, Ground Stations, etc.
  - Spacecraft level – Subsystems and interfaces that make up spacecraft
  - Subsystem – Components and technologies that make up subsystem
- Architect's role is to ensure customer requirements and needs are properly addressed in the system
  - Identifies utility and flexibility of the system
  - Optimizing architecture can make spacecraft trades easier

The Design Process

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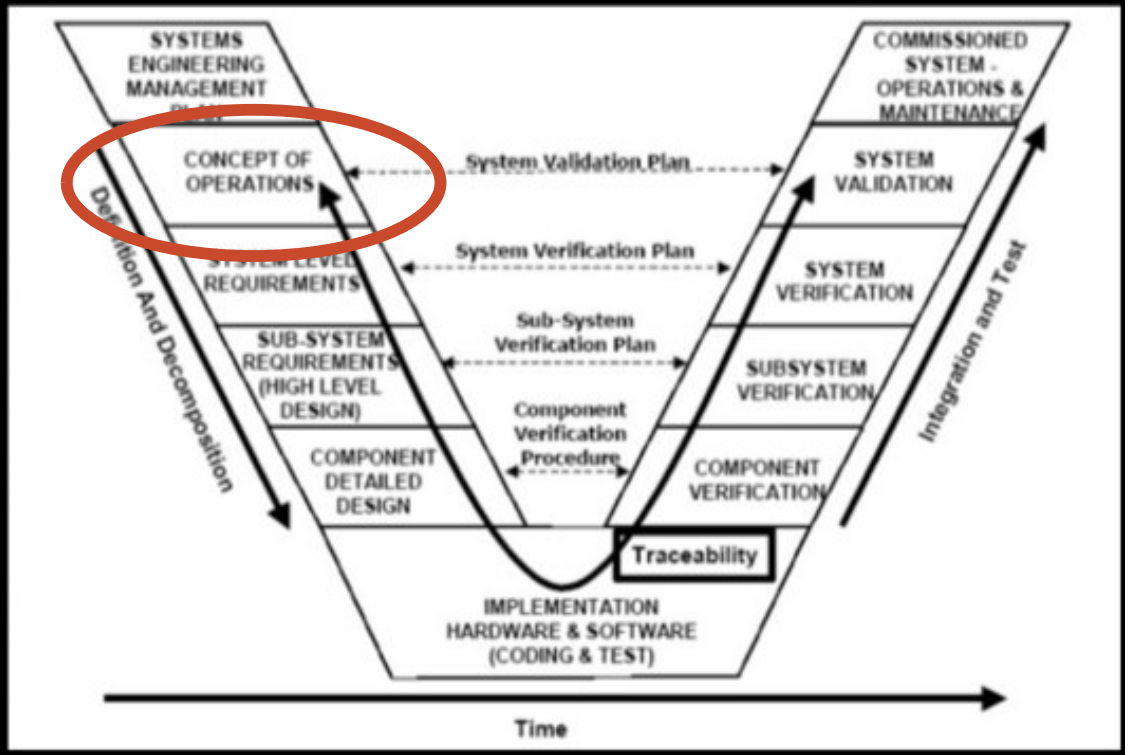
- Systems Approach
- CONOPS
- Requirements
- Design Reviews



Concept of Operations

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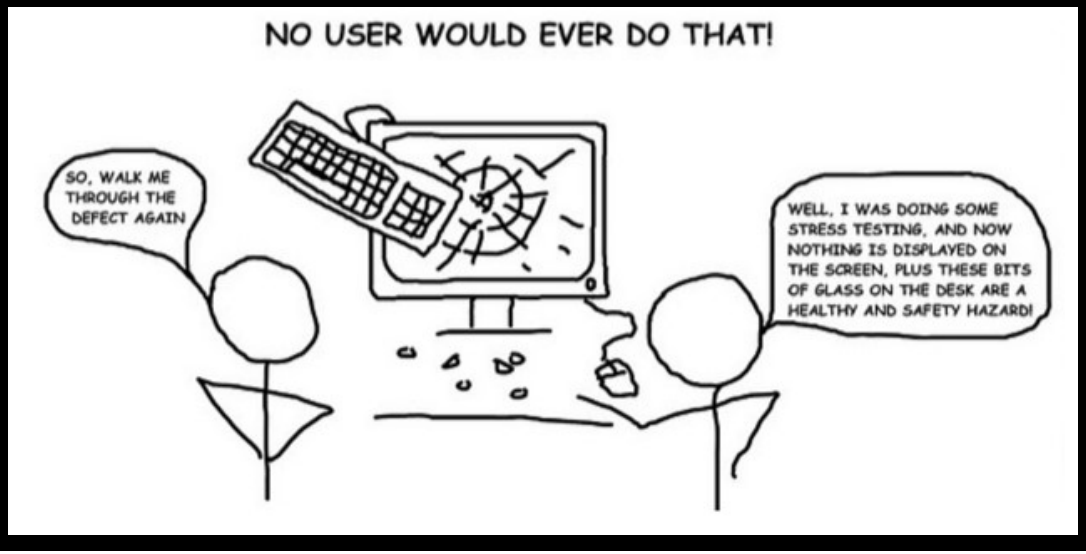
- Concept of Operations (CONOPS)
  - How the system will be used
  - Links technical requirements with user's needs
    - Requirements do not fully represent customer's wishes…
  - Operational scenarios, timelines, block diagrams, orbital maneuvering among the products
  - Examples: Assignment Requirements do not specify how often payloads need to operate, could reduce overall power required



CONOPS Example

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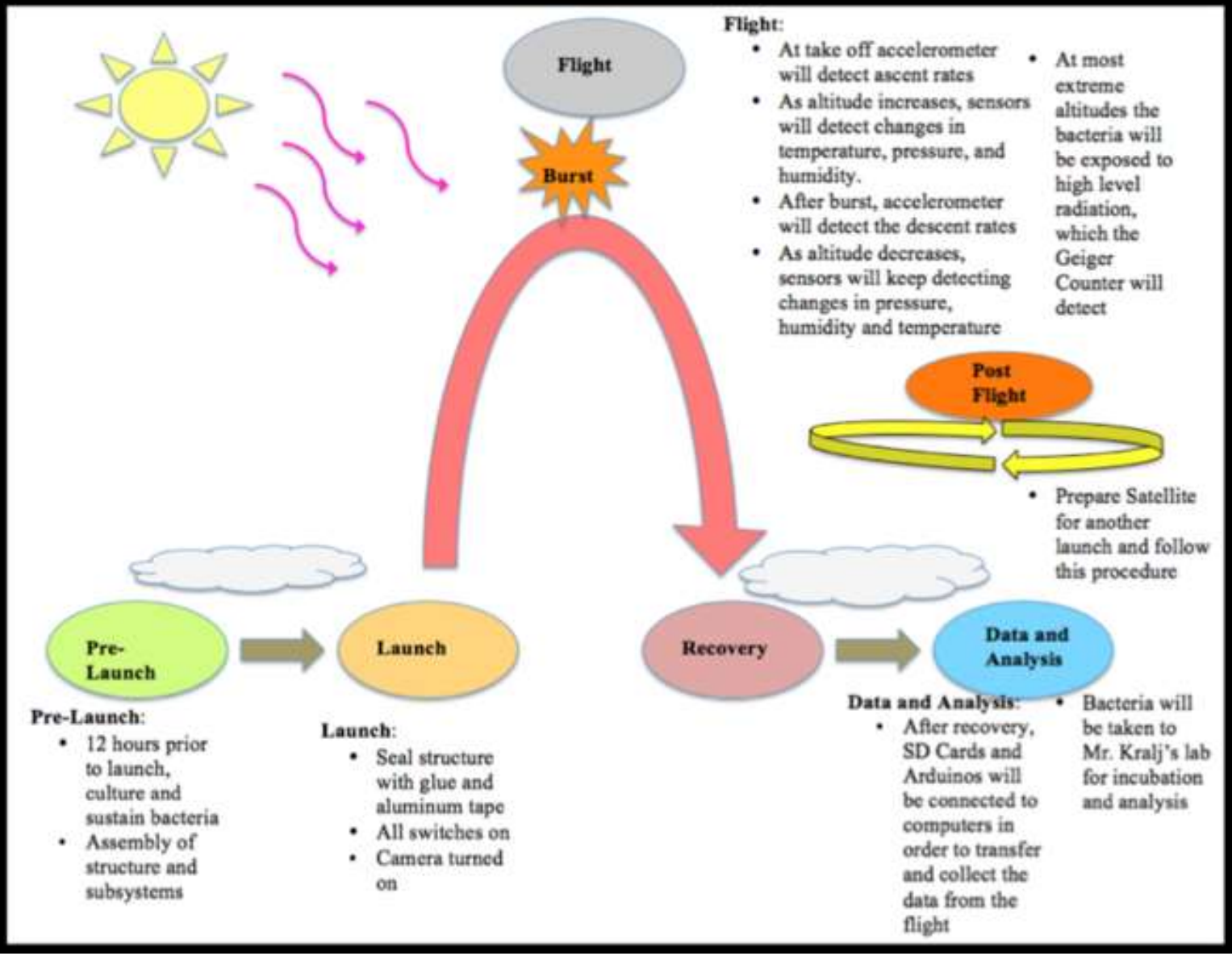

CONOPS - Examples

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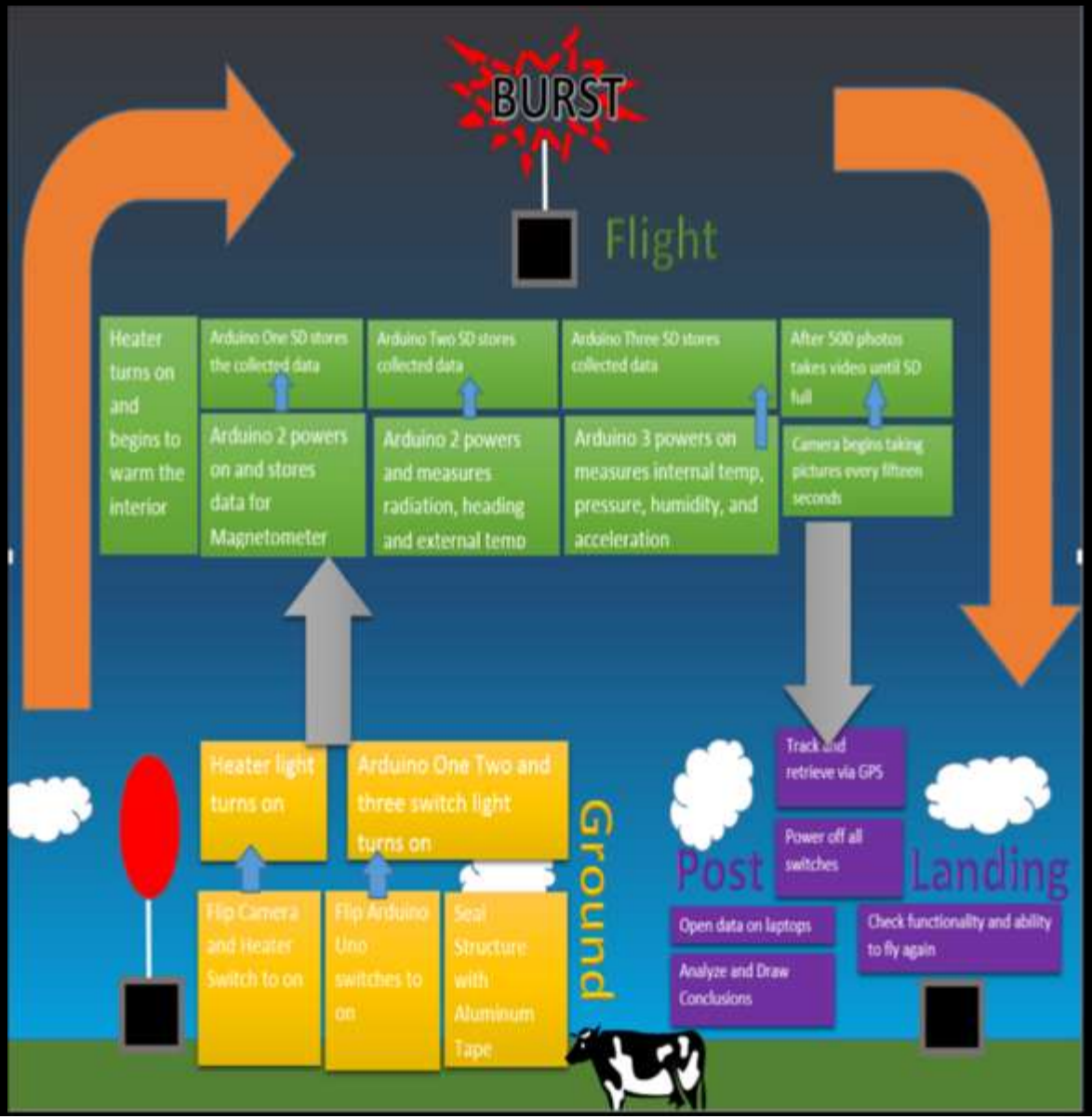

CONOPS - Examples

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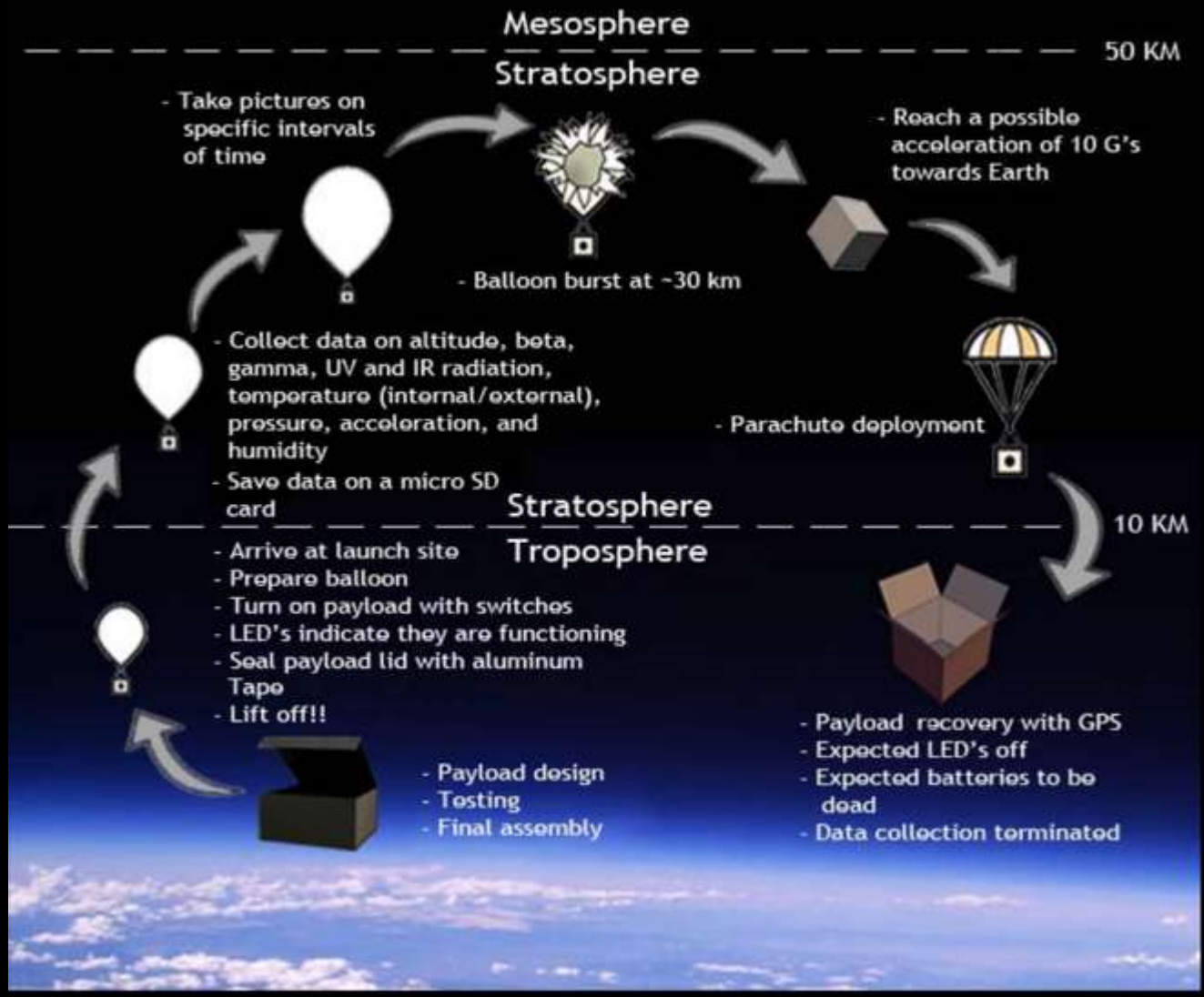

CONOPS - Examples

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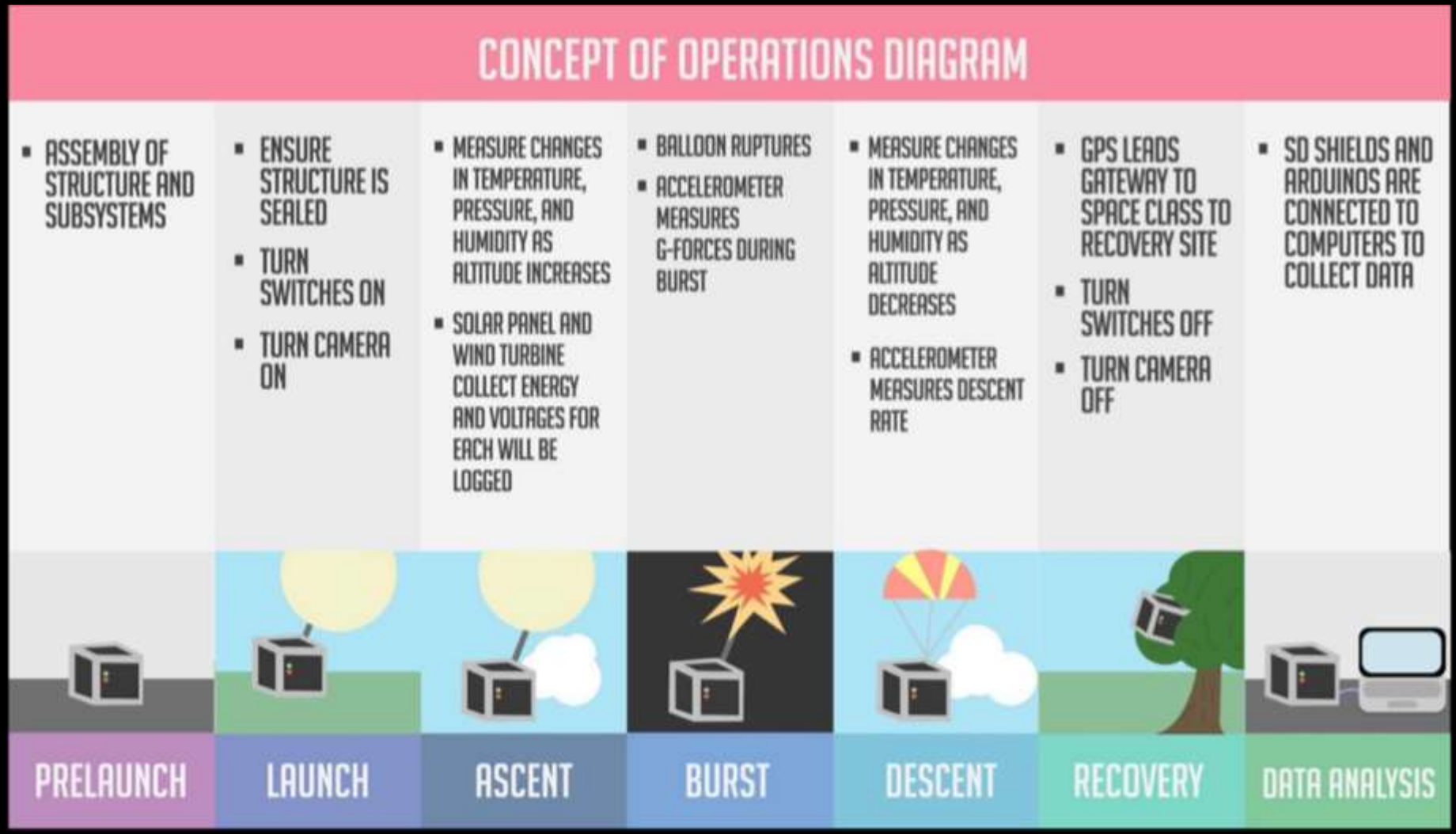

The Design Process

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- Systems Approach
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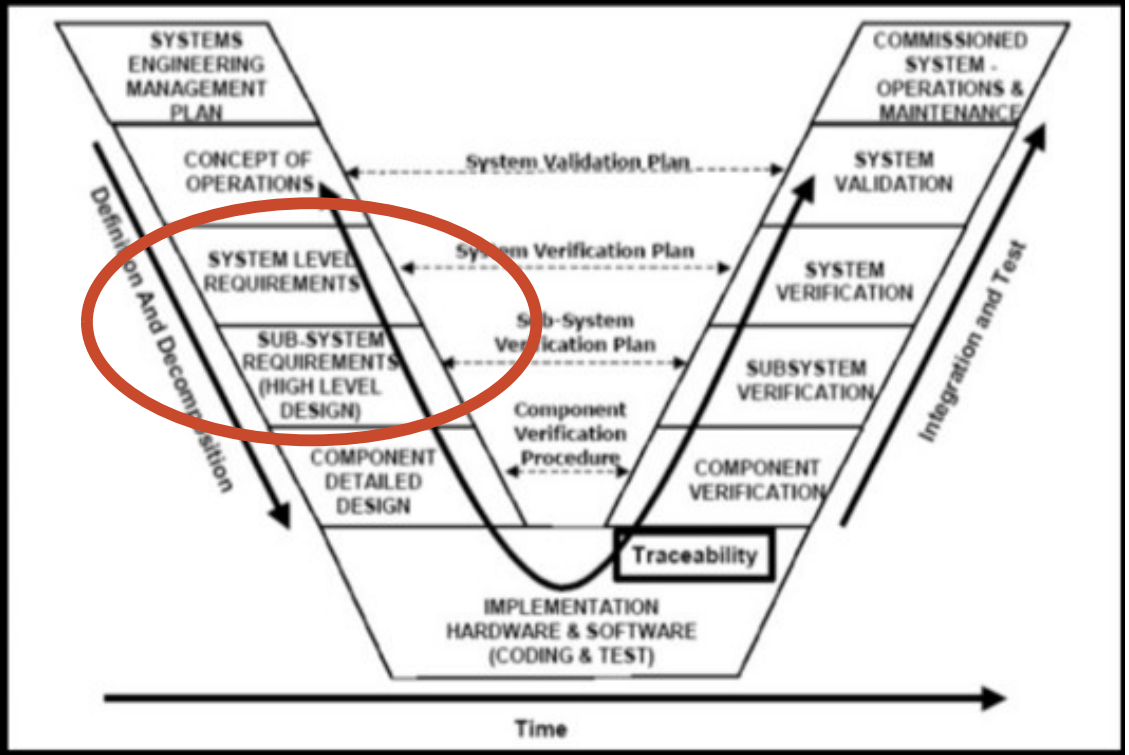

Requirements

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- What is a requirement?
  - Requirements define the design space and thus the project. They DO NOT DEFINE the MISSION.

- Why spend time on requirements?
  - They let you know when you are done. (with implementation and finally verification)

Requirements

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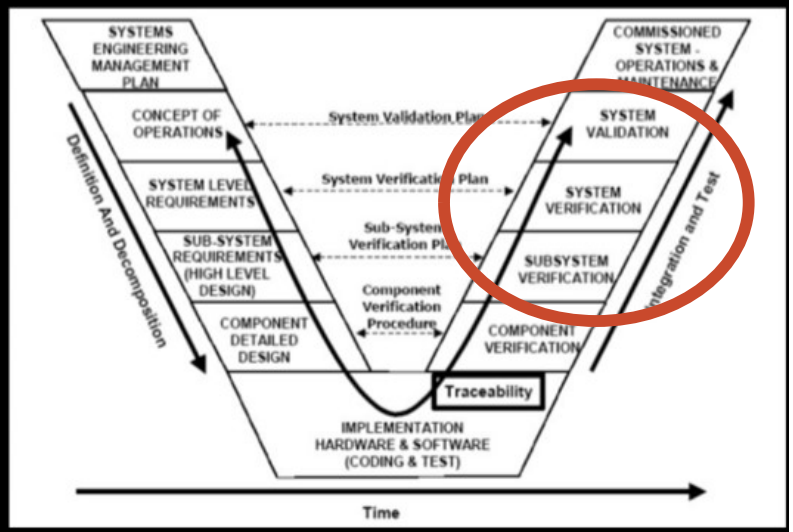
- What is the difference between verification and validation?

- Verification = build the thing right

  You captured the performance

- Validation = Build the right thing

  You captured the spirit



Requirements

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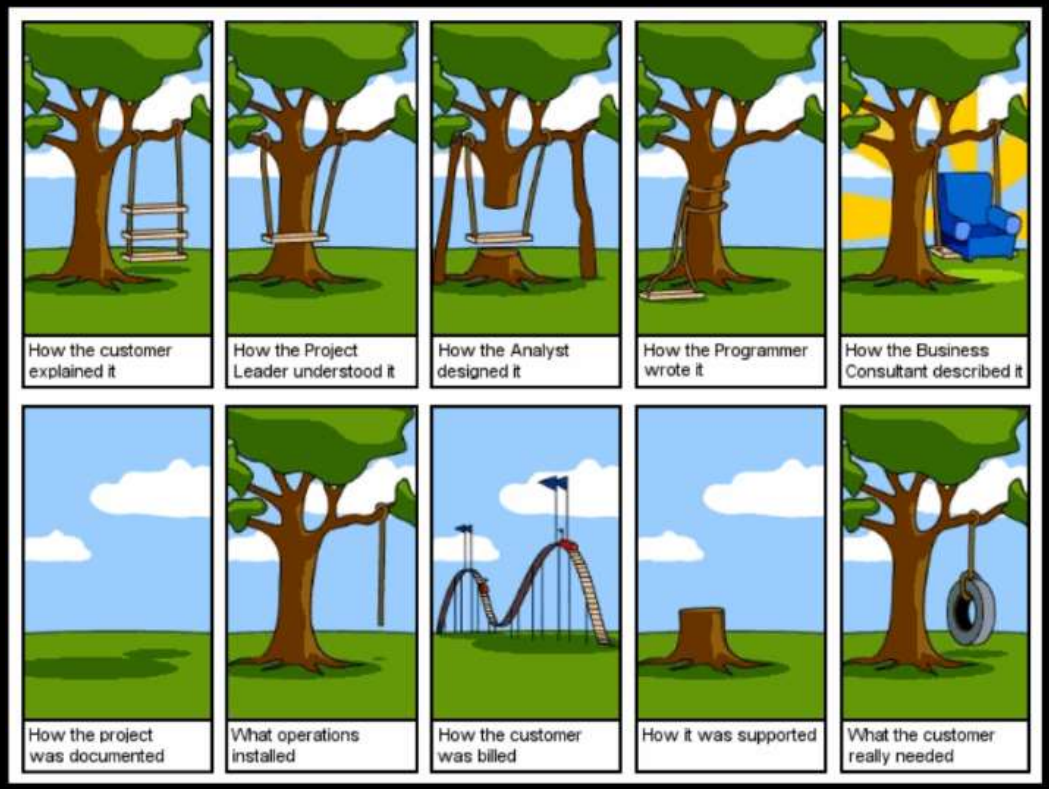
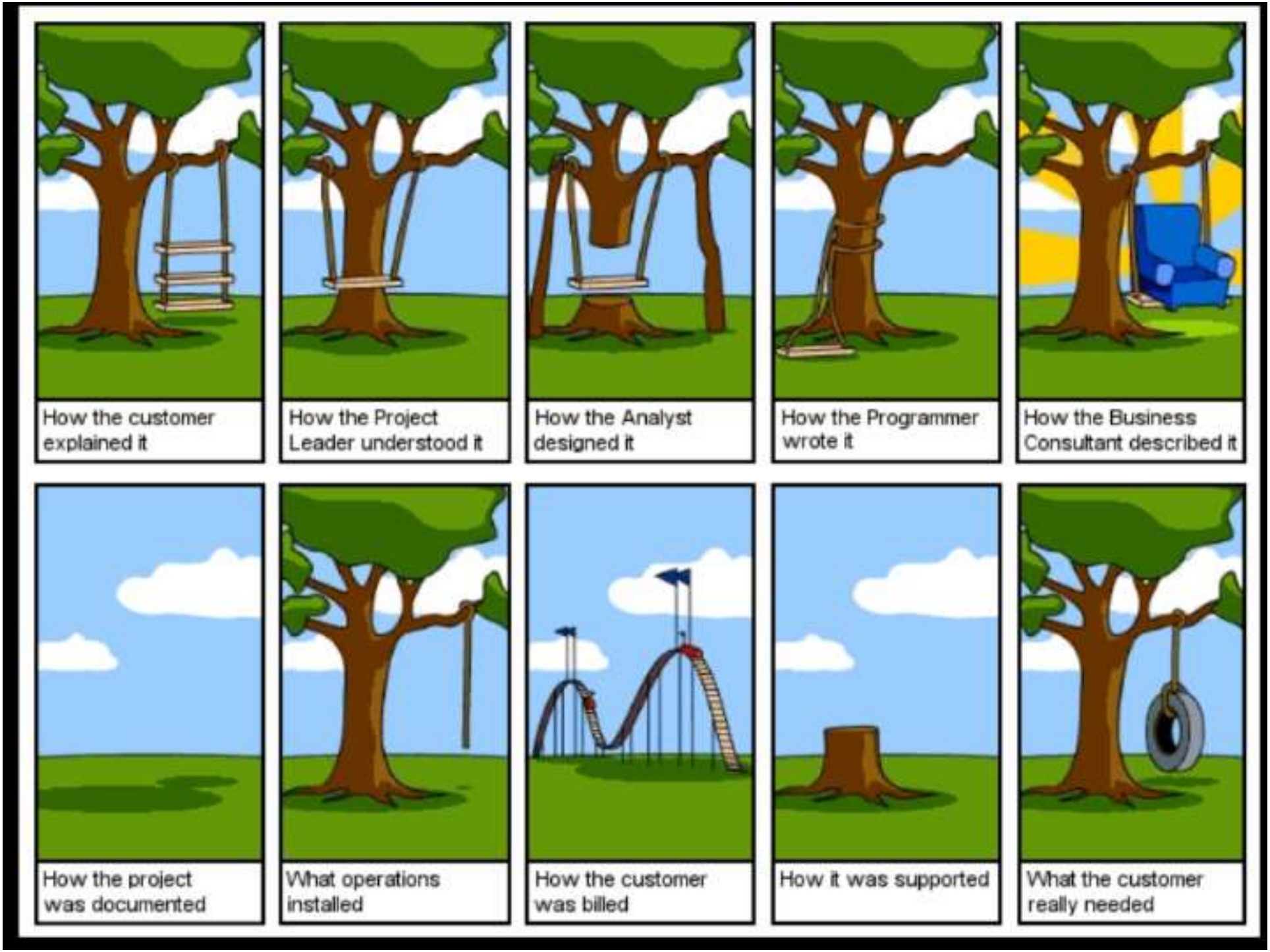
- Requirements make sure that the end product comes out as the customer desired it to (validation) with the performance to accomplish the job (verification)




How the customer explained it
How the Project Leader understood it
How the Analyst designed it
How the Programmer wrote it
How the Business Consultant described it
How the project was documented
What operations installed
How the customer was billed
How it was supported
What the customer really needed

Requirements

- Five aspects of a good requirements

1. **CLEAR**
2. **NECESSARY**
3. **TRACEABLE**
4. **ATTAINABLE**
5. **HAVE A METHOD OF VERIFICATION**

Requirements

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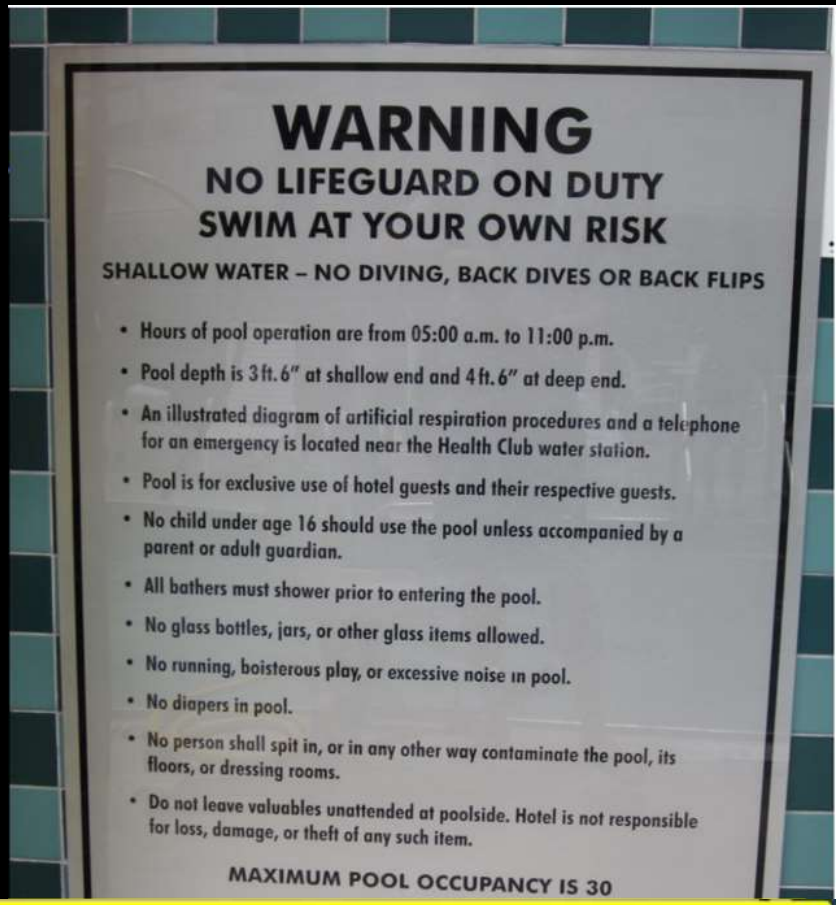
1. CLEAR

- Make sure you, your customer, AND your team understand the goals
- Every requirements should capture one idea, not multiple at a time



No person shall spit in, or in any other way contaminate the pool, its floors, or dressing rooms.

Requirements

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2. NECESSARY

- A statement of need for a problem/challenge

- Statements that define capabilities needed to meet the mission

What is the worst thing that could happen if this requirement were not included? - If you do not find an answer of any consequence, then you probably do not need the requirement.

Requirements

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3. TRACEABLE

A requirement should be able to be traced all the way back to the mission statement

- Exists in a hierarchy of breaking down the problem
- Lower level requirements answer this fundamental question "What do I have to do with do X or Y?"

Requirements

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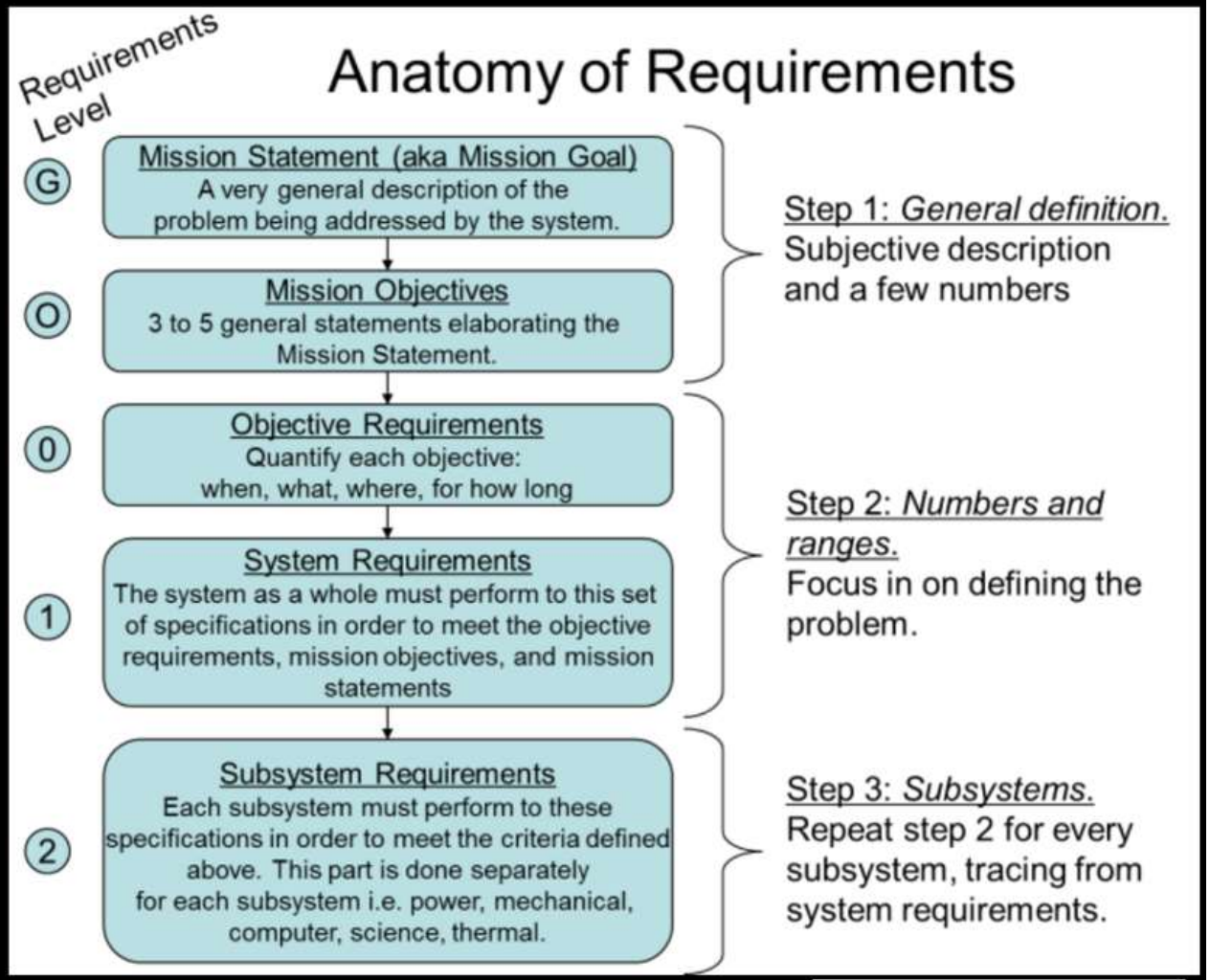
- Requirements flow from your mission statement and mission objectives
- They are always traceable back to the mission statement



*Koehler & Pilinski 2007

Requirements

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1.0 Mission Statement

Team Rocket's mission is to design, build, and launch a BalloonSat into near-space to measure the effects wildfires have on the atmosphere to an altitude of 30 km above Colorado. Project Fire Hazard will measure these effects by testing the levels of carbon dioxide (CO_2), particulate matter (PM), and volatile organic compounds (VOCs). This mission will be completed through the Gateway to Space course at the University of Colorado at Boulder instructed by Chris Koehler. Team Rocket aims to correlate the levels of VOCs, CO_2 , and PM molecules in the atmosphere with the recent local and nearby (California) wildfires.

Requirements

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Level 0 requirements	Description	Origin
0.0	Team Rocket shall launch a BalloonSat that shall rise to 30 km on a high altitude balloon.	Mission Statement
0.1	Project Fire Hazard shall measure and analyze levels of various gasses and particles in the atmosphere above Colorado, USA.	Mission Statement
0.2	Team Rocket shall find the effects of current wildfires using the data collected by Project Fire Hazard.	Mission Statement
0.3	Team Rocket shall recover Project Fire Hazard with the recorded data once it returns to Earth	Mission Statement
0.4	Project Fire Hazard shall follow all guidelines outlined by the ASEN 1400 Request for Proposal.	Request For Proposal

Requirements

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Level 1 Requirements	Description	Origin
1.0	Team Rocket shall launch a balloon satellite that is equal to or less than 800 grams.	0.4
1.0	Team Rocket shall conduct rigorous tests in order to ensure the survivability of Project Fire Hazard in strenuous environments including extreme cold and violent motion.	0.4
1.3	Team Rocket shall measure CO_2, particulate matter, volatile organic compounds, temperature inside and outside the BalloonSat, pressure, humidity, and acceleration.	0.1
1.4	Project Fire Hazard shall have sufficient battery life to last three hours.	0.4
1.5	Team Rocket shall analyze data recovered from flight to find a correlation between current forest fires and CO_2, VOCs, and particulate matter.	0.2

Requirements

4. ATTAINABLE

- A design challenge should be physically possible, and requirements help bound the problem
  - *A requirement must be met (at some point)*
  - *Lack of resources, design methods, and human smarts must be taken into account*
  - *Don't forget yourself saying, "well it was too hard"*

5. Have a Method of Verification

- If you have a need then you must verify your end product meets that need (performance)

To truly answer the question, "are you done and ready to fly?" you must have verified each of your requirements

Requirements

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To see if your project is truly done, we go back to our verification and validation.

Verification

"Did we build the system right?"

Validation

"Did we build the right system?"

Requirements:

Examples

- A black sports car shall reach 60 mph in 3 seconds

Requirements

Examples

A black sports car shall reach 60 mph in 3 seconds

Lacks traceability and Necessity

Requirements

Examples

EPS may consume 70W at 5V and 12V

Requirements

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Examples

EPS may consume 70W at 5V and 12V

Lack Clarity (how long?)

Requirements

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Examples

A space imager will be cooled to 0K to monitor Thermal IR

Requirements

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Examples

A space imager will be cooled to 0K to monitor Thermal IR

Lacks Attainability and Verification

Requirements

Examples

The purple spacecraft, brought to you by Carls Jr, shall carry 10 cats and should be in a 30 mile orbit above Earth and has to stay over Boulder 24 hours a day.

Requirements

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Examples

The purple spacecraft, brought to you by Carls Jr, shall carry 10 cats and should be in a 30 mile orbit above Earth and has to stay over Boulder 24 hours a day.

Requirements

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Do Not Tell HOW

BobSat shall measure the rotation rate of the BalloonSat through the duration of your flight.

BobSat shall measure the rotation rate of the BalloonSat in three axes to a resolution of 0.1 degree/sec using a magnetometer and gyroscope from SparkFun for 15 minutes of the flight.

- A requirement should bound the solution but not be the solution

Requirements

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The Right Words:

Standardized Wording

SHALL: Something that must be verified in the final design

SHOULD: A stretch goal of the project (i.e. pie in the sky)

WILL: Statements that are facts or explanations

Star Wars/Yoda was right!

"There is no try, only do or do not!"

Requirements

The Wrong Words:

Don’t use words that are vague like:

Minimum, Maximum, Average, Better, Worse, Maximize, Minimize, Simultaneous, Rapid, Real-time, Satisfactory, Adequate, Sufficient, Always, Sometimes, May, Most, Ideal(ly), Significant(ly)

Your requirements should be strong and self-supporting; these words aren’t

Avoid being wordy in your requirements, generally that leads to capturing multiple goals at the same time, each requirements should convey one point.

Requirements

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Even now as you write your requirements consider:

- How are you going to make sure you meet them in the end?
- What kind of testing are you going to need?
- How will you turn the testing data into something meaningful?
- Converting voltages from a sensor into units (C, psi, G, etc)?
- Characterization of your experiment so that you know the data you gather on flight is correct?
- Fundamentally you are answering the question of will your Balloon Payload survive without you for 4 hours
- Consider doing a full mission simulation to show (never guess) that you can meet your mission

The Design Process

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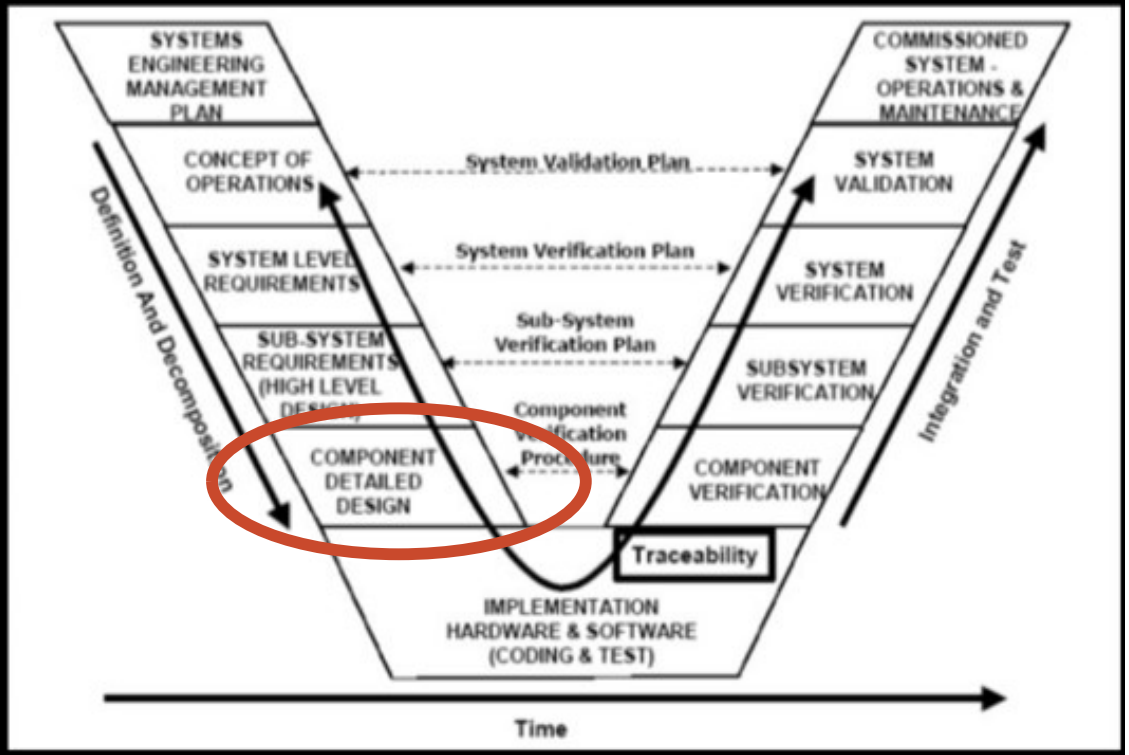
- Systems Approach
- CONOPS
- Requirements
- Design Reviews



Design Reviews

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- The purpose of Design Reviews
  - During a project build, it is necessary to evaluate the product design and development against project requirement.

- Depending on the project needs, the scope and magnitude of the project, various Design Reviews may be needed.

Design Reviews

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- Systems Requirements Review (SRR)
- Systems Design Review (SDR)
- Conceptual Design Review (CoDR)
- Preliminary Design review (PDR)
- Critical Design Review (CDR)
- *Other custom reviews*
- Safety Reviews
- Manufacturing Readiness Review (MRR)
- Test Readiness Reviews (TRR)
- Integrated Test Reviews
- Final Design Review (FDR)
- Launch Readiness Review (LRR)

Design Reviews

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- What is a Preliminary Design Review?

The Preliminary Design Review (PDR) is a technical review for the team to establish the allocated baseline (hardware, software, human/support systems) and underlying architectures to ensure that the system under review has a reasonable expectation of satisfying the requirements within the currently allocated budget and schedule.

Design Reviews

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- Completion of the PDR should provide the following:
  - A Mission Overview
  - Updated System and Subsystem Requirements
  - Schematics/Drawings/Analysis and Block diagrams
  - Test plans
  - Parts list
  - Team and project management
- PDR Guidance
  - Each team will have XX minutes for presentation and XX minutes for questions
  - Don’t go over time

Design Reviews

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- What is a Critical Design Review?

A Critical Design Review (CDR) is a technical review to ensure that a system can proceed into fabrication, demonstration, and test and can meet stated performance requirements within cost, schedule, and risk.

Design Reviews

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- Completion of the CDR should provide the following:
  - A Mission Overview
  - Concept of Operations
  - Schematics/Drawings/Analysis and Block diagrams
  - Test plans
  - Expected Data
  - Associated Challenges or Long poles of the project
- CDR Guidance
  - Each team will have XX minutes for presentation and XX minutes for questions
  - Don’t go over time

Design Reviews

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- What is a Launch Readiness Review

- A Launch Readiness Review (LRR) ensures that your payload is ready for flight and won't compromise any of the other payloads, or the launch balloon or site.

Launch Readiness Review

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- Completion of the LRR should provide the following:
  - A Mission Overview
  - Design Overview
  - Test results
  - Predicted Launch data
  - Go / NO GO for flight

- LRR Guidance
  - Each team will have XX minutes for presentation and XX minutes for questions

  - Don’t go over time