Project Management Fundamentals

Using NASA project management concepts for physics instrumentation projects

Aaron Pearlman (aaronjp@illinois.edu)
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Physics 524

Introduction

- My experience at NASA/NOAA is supporting building, testing, and operating (mostly-) Earth observation satellites for weather and climate applications — involved applying project management principles

Some background on project management at NASA

- Critical at NASA (e.g., Apollo, Shuttle, Mars rovers).
  - Ex. Apollo: Complicated system with new technologies, tight timeline (1961 mandate, by 1970 landing on the moon)
    - Milestones, critical path concepts, phased reviews
    - Coordination among huge teams (100,000's of people)
    - Risk management (redundancy, simulations, contingency planning) - way more risk accepted for human space flight than nowadays
    - Lessons Learned (Apollo 1 fire)
  - Ex. GOES-R: Geostationary satellite with multiple instruments: Imager, lightning mapper, space weather instruments
    - Many different instruments on the same platform
    - Had to be an operational instrument — requirements for reliability dominated (leads to using mature technologies)
- **The practices (systems thinking, risk management, stage gates) spread across aerospace, defense, construction, IT, healthcare, and beyond, forming much of what we now consider modern project management.**

Project life cycle

- What is a project? a temporary endeavor with a defined goal and deliverables.
  - Need to balance between scope, time, cost, and quality (the “iron triangle”)
  - Has phases to define its life cycle: NASA missions (proposal → design → build → launch → mission ops → post-mission).

Phases:

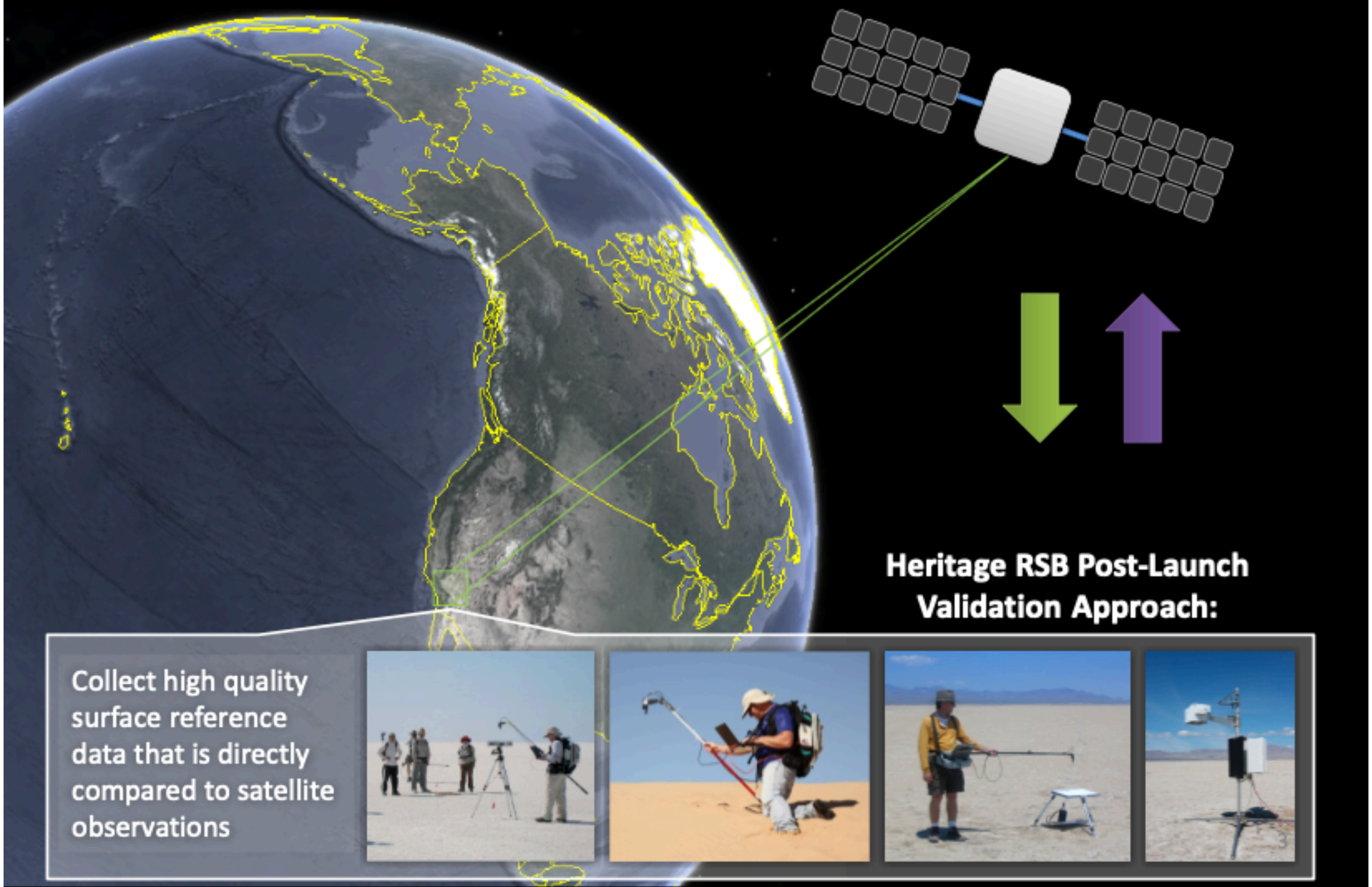
- **Initiation** – defining the mission/need, stakeholder buy-in.
- **Planning** – developing objectives, schedule, resources, risk analysis.
- **Execution** – carrying out the plan, managing teams.
- **Monitoring & Controlling** – tracking progress, adjusting.
- **Closing** – lessons learned, documentation, handover.

Defining scope and objectives

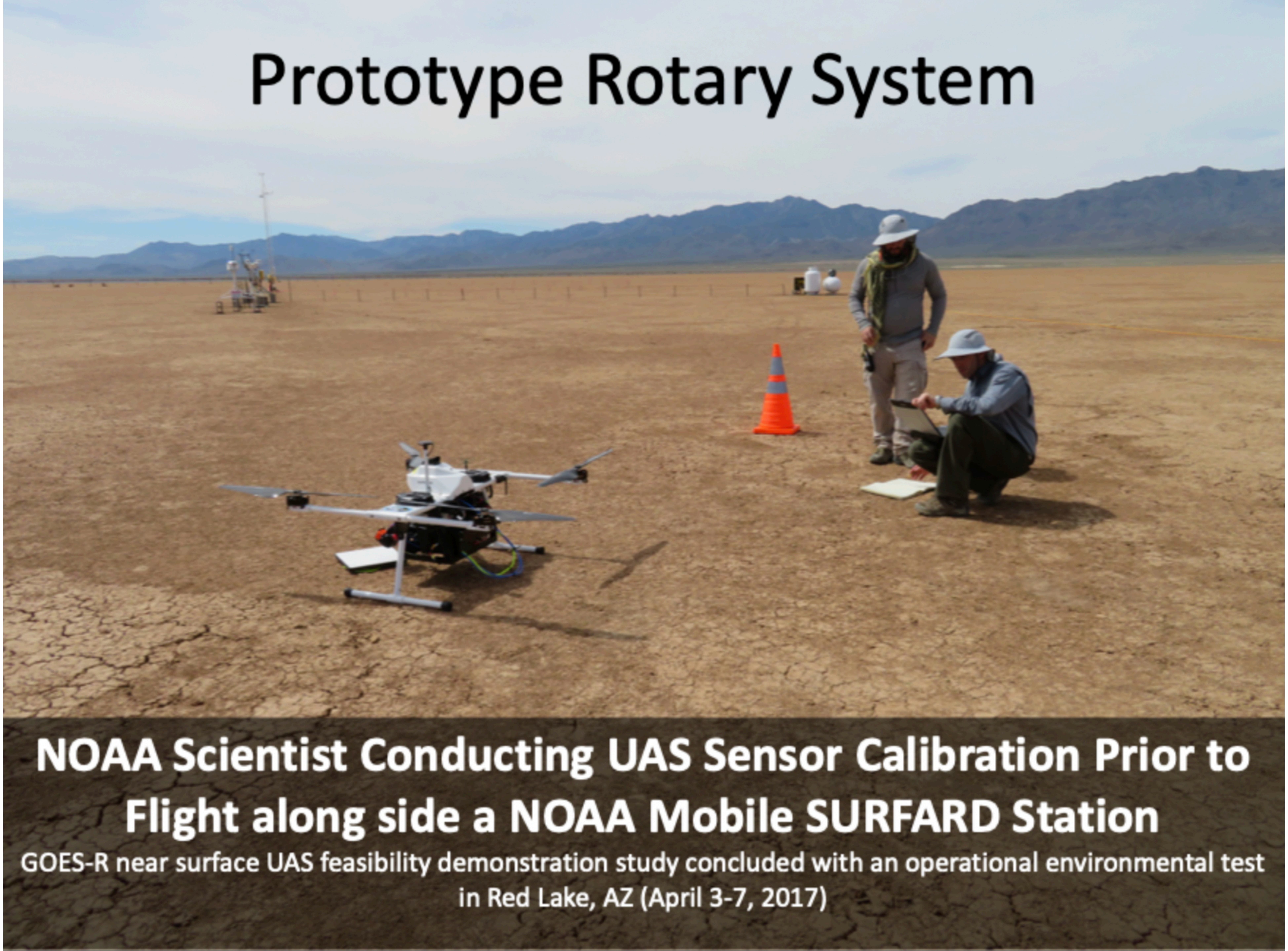
- Write a clear project goal -
  - Building a system for what purpose?
  - What level of maturity is needed to meet your goals?
- Importance of requirements definition (technical, functional)
  - Should be informed by the science objective: what measurement are we trying to make?
  - Requirement examples: System has to reach temperature and hold it for duration, or has to detect muons with a specified sensitivity…
- Create a Work Breakdown Structure (WBS): decomposing large objectives into manageable tasks.
    - To assist in formulating WBS, you can list all of the major components of each element in your system (called a Product Breakdown Structure)

Let's work through an example to illustrate these steps…

High to Moderate Resolution Satellite Sensors Leverage Small Uniform Earth Targets for Post-Launch Validation



Prototype Rotary System



NOAA Scientist Conducting UAS Sensor Calibration Prior to Flight along side a NOAA Mobile SURFARD Station

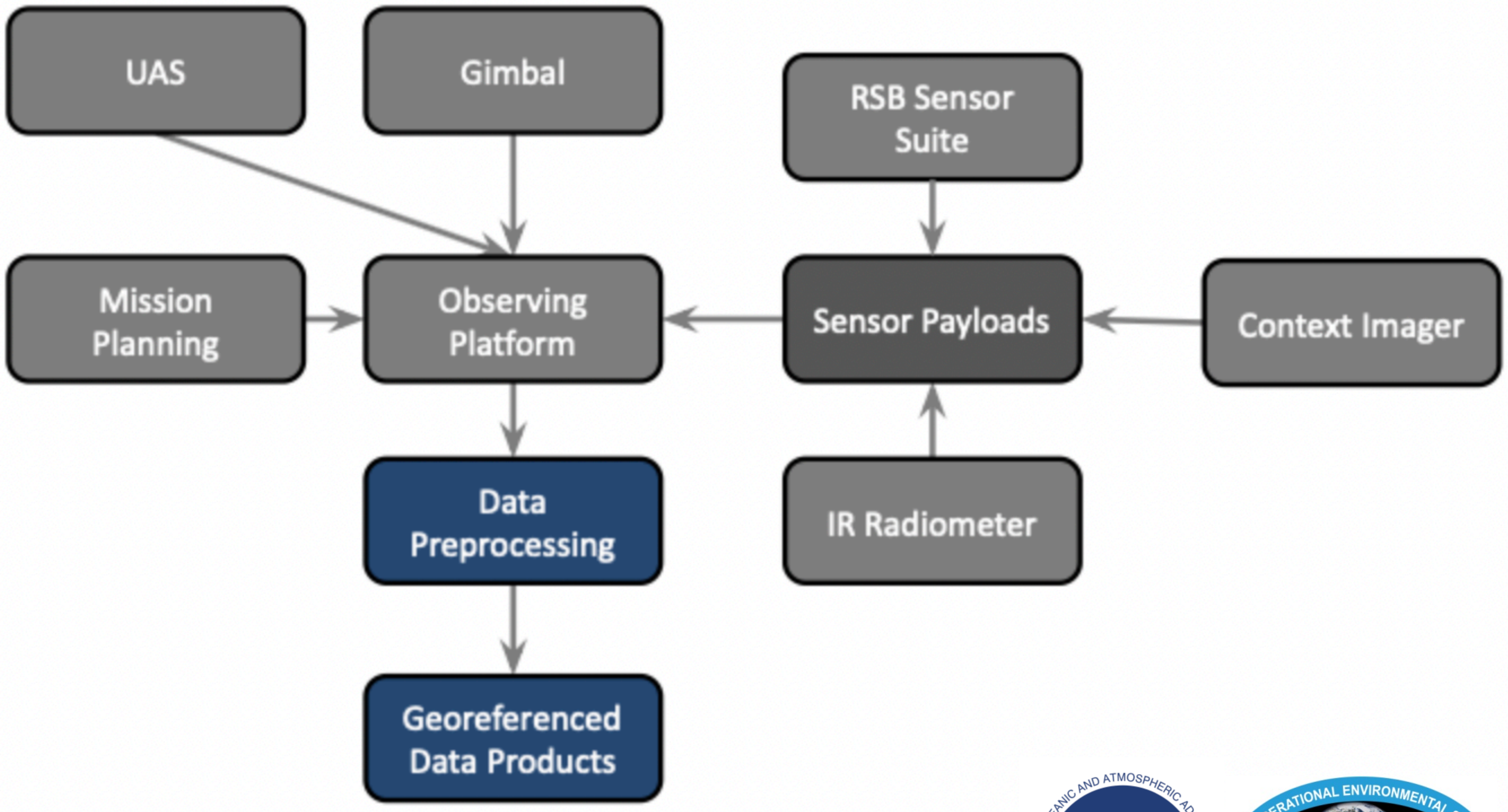
GOES-R near surface UAS feasibility demonstration study concluded with an operational environmental test in Red Lake, AZ (April 3-7, 2017)

UAS Near-surface Feasibility Demonstration Study

- Goal: To validate a satellite sensor's radiometric performance by making near-surface measurements with a UAS-based sensors system

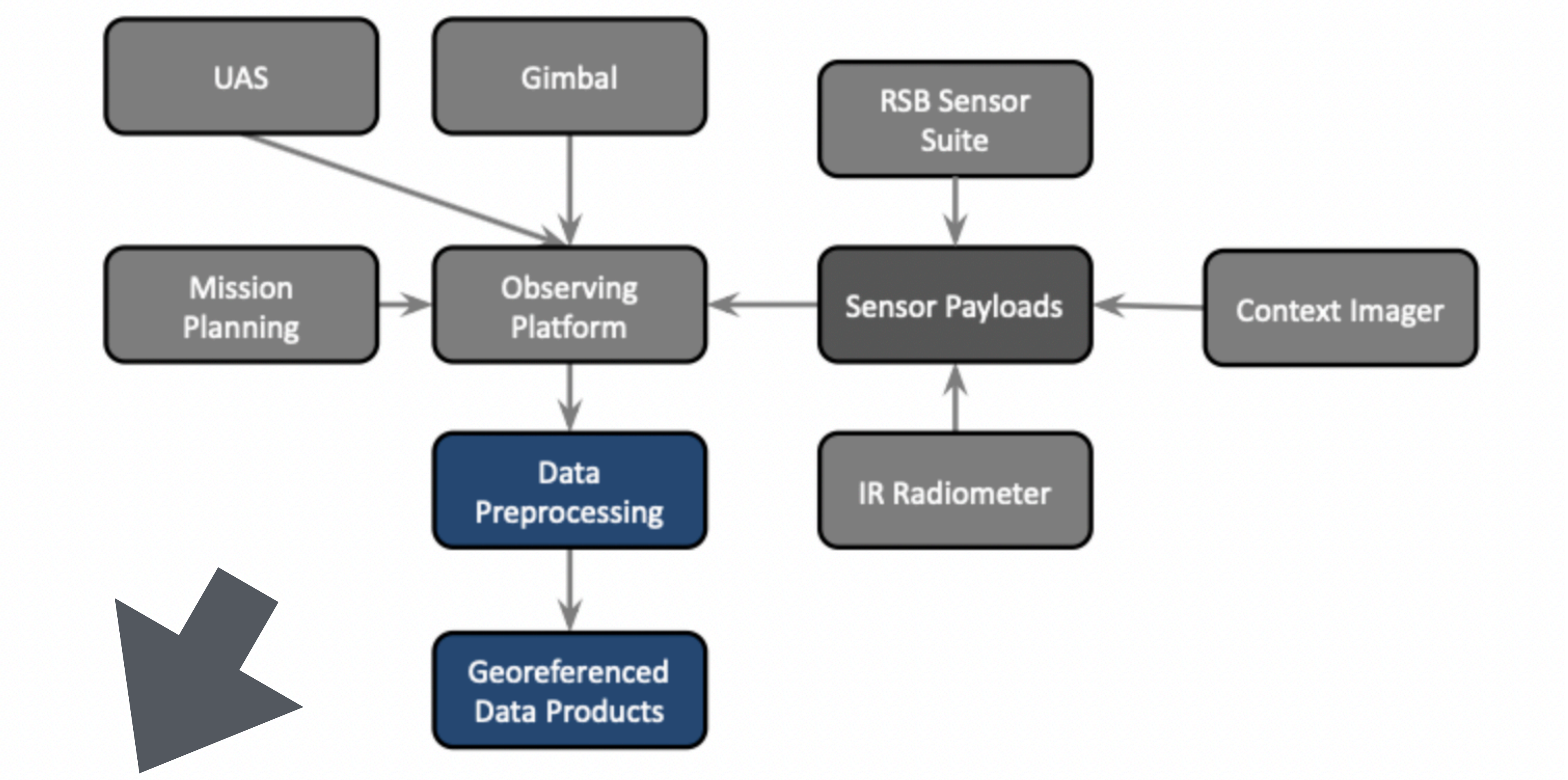
- Requirement: <5% radiometric uncertainty (k = 1)

- Product Breakdown Structure - shows the physical/functional components of the system



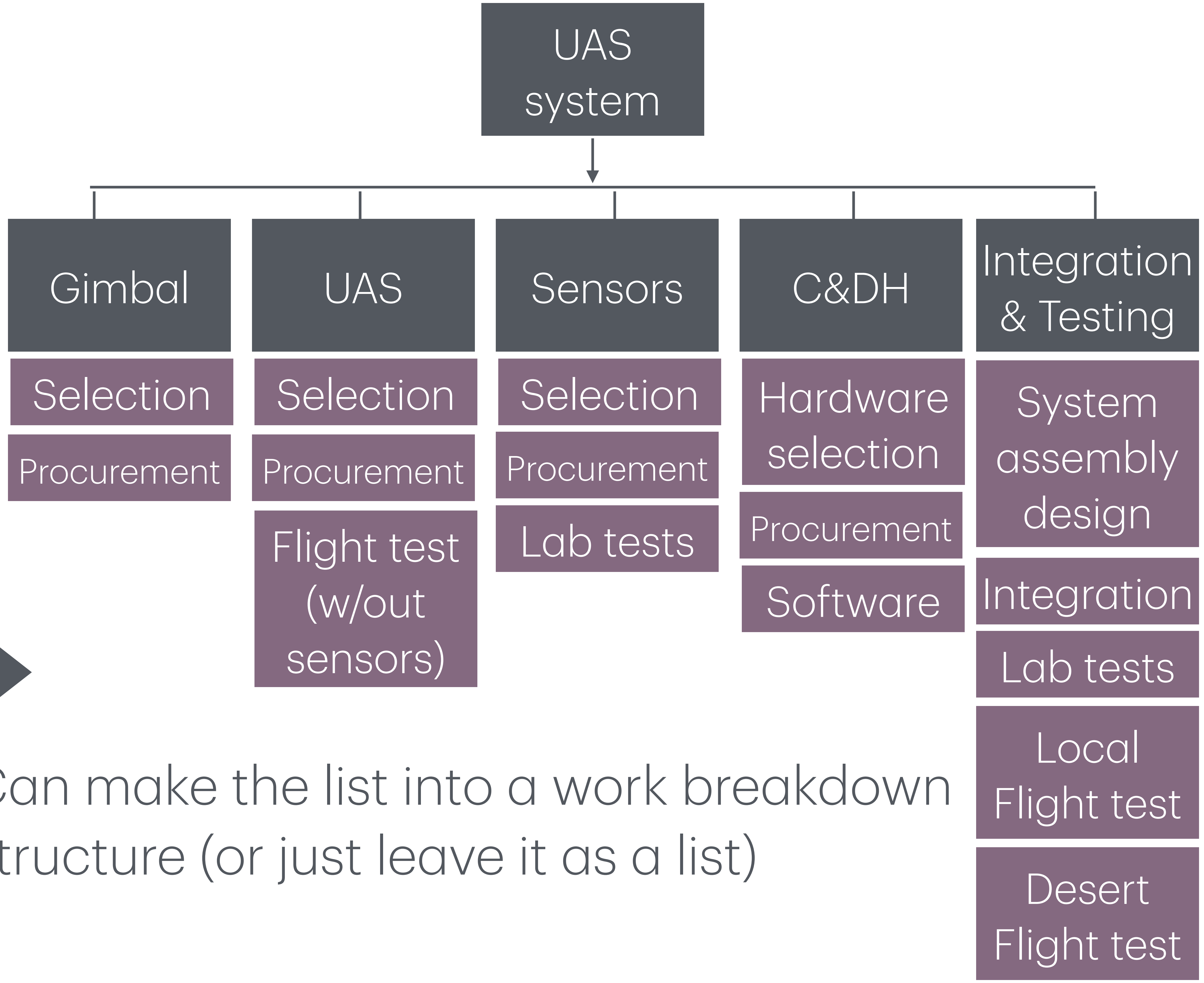
Work breakdown structure

From product breakdown structure, **create a list of tasks**



Tasks

- UAS selection
- Sensor selection
- Command and data handling (hardware and software)
  - Includes UAS flight control, gimbal pointing control, sensor parameter adjustment, triggering, sensor and UAS (ex. GPS) data recording,
- Assembly design (how to integrate hardware onto UAS platform)
- Procurement of UAS and sensors
- Test sensors individually
- Integrate the sensors together and test
- Test the UAS (with weights) to check expected flight time, maneuverability

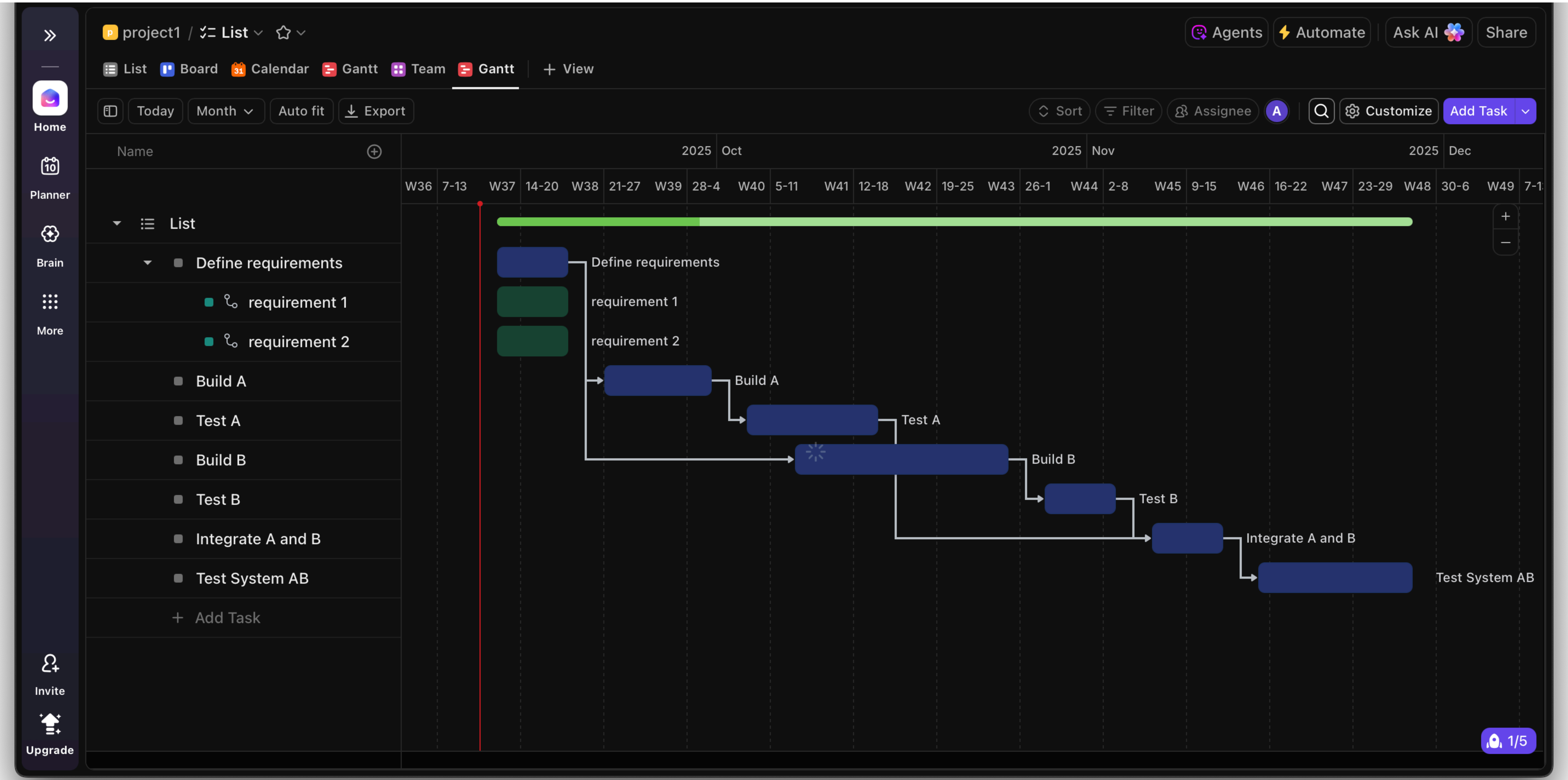


Can make the list into a work breakdown structure (or just leave it as a list)

Making a schedule

Made using ClickUp software (may identify the critical path in correctly)

- Quick demo using software (ClickUp) to form the schedule and identify the critical path
- Tasks
    - Define Requirements
    - Build A
    - Test A
    - Build B
    - Test B
    - Integrate A and B
    - Test System AB



Critical path: The longest sequence of dependent tasks in a project that determines the shortest possible completion time.

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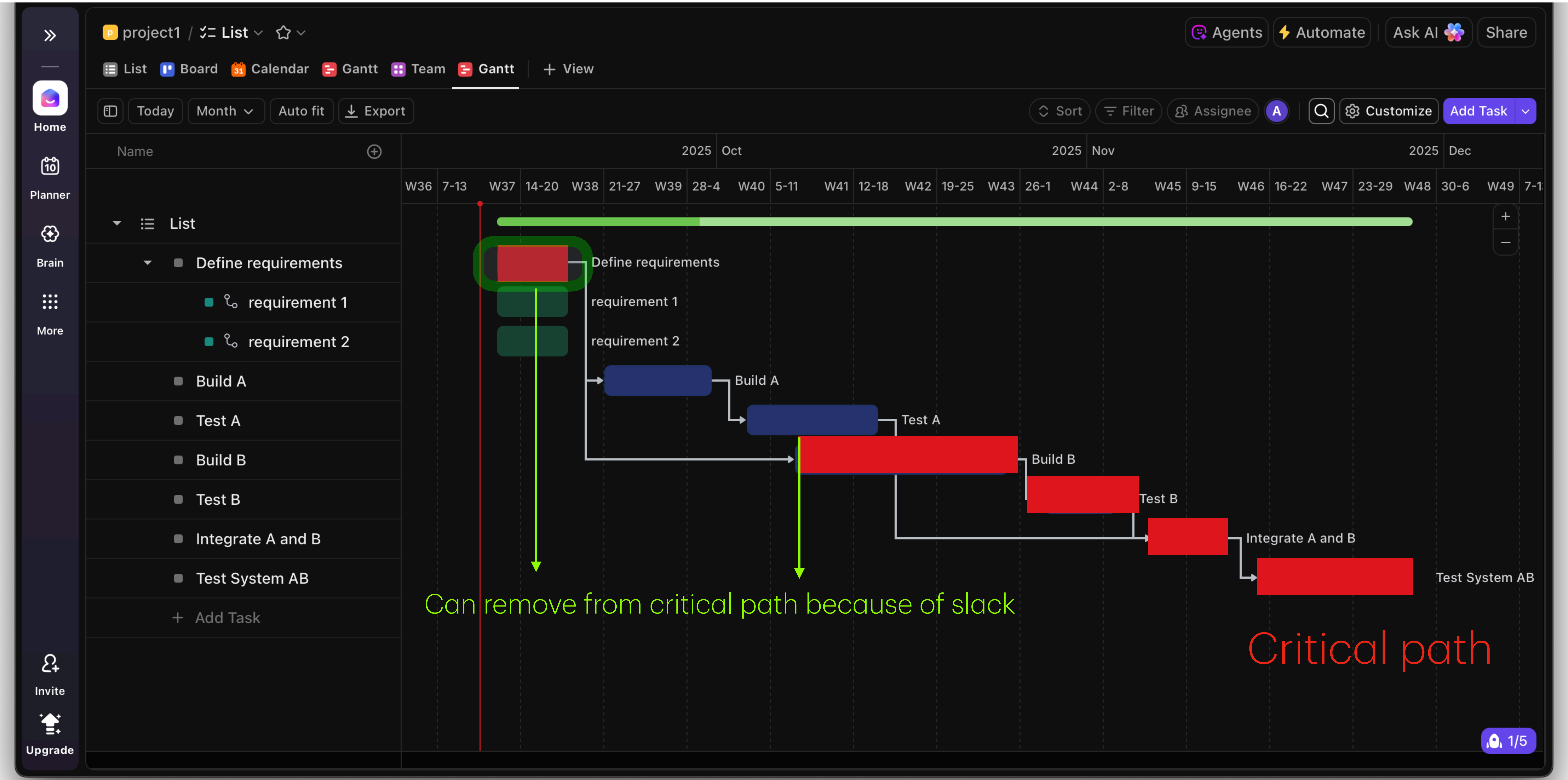

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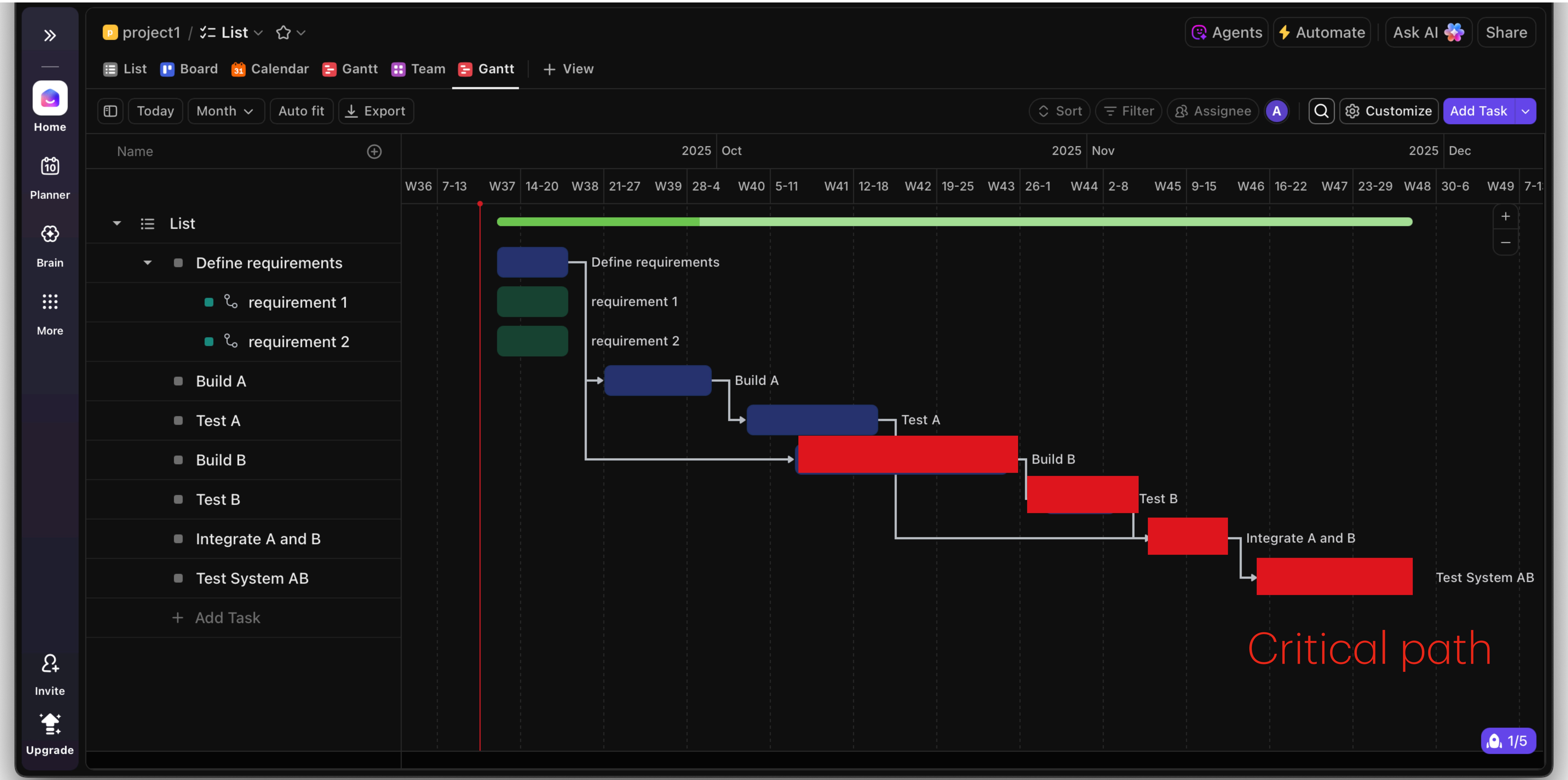

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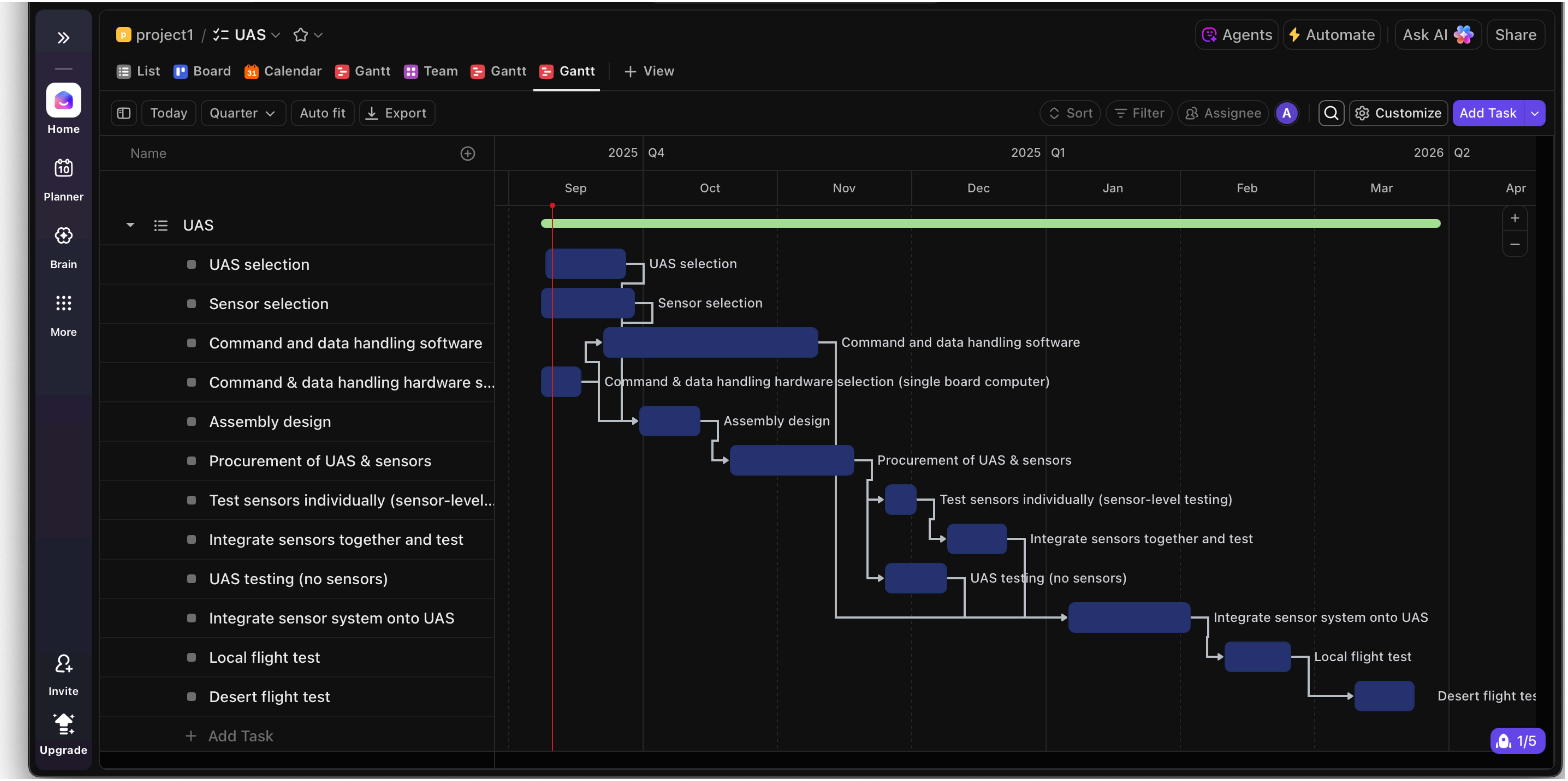
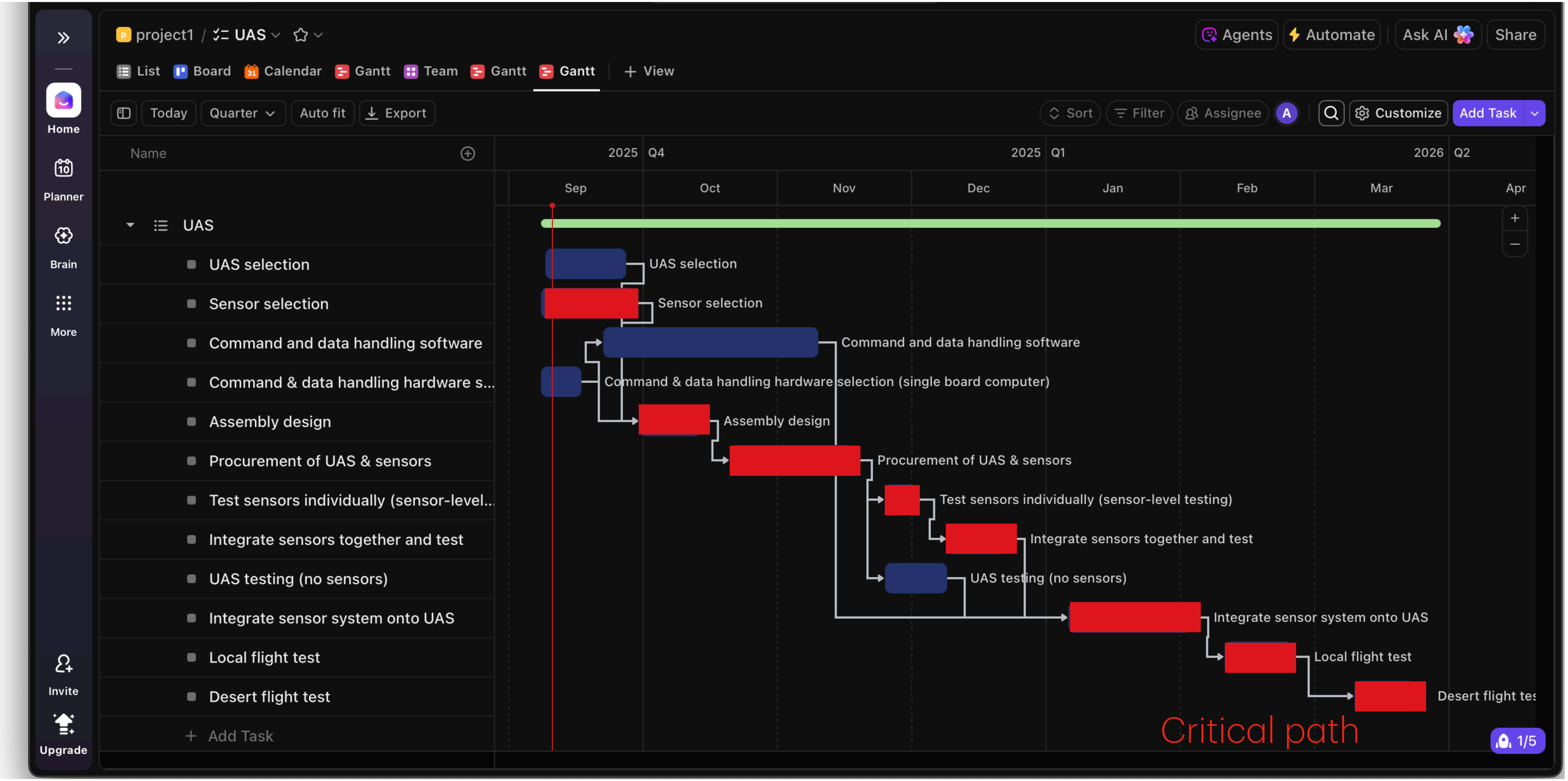
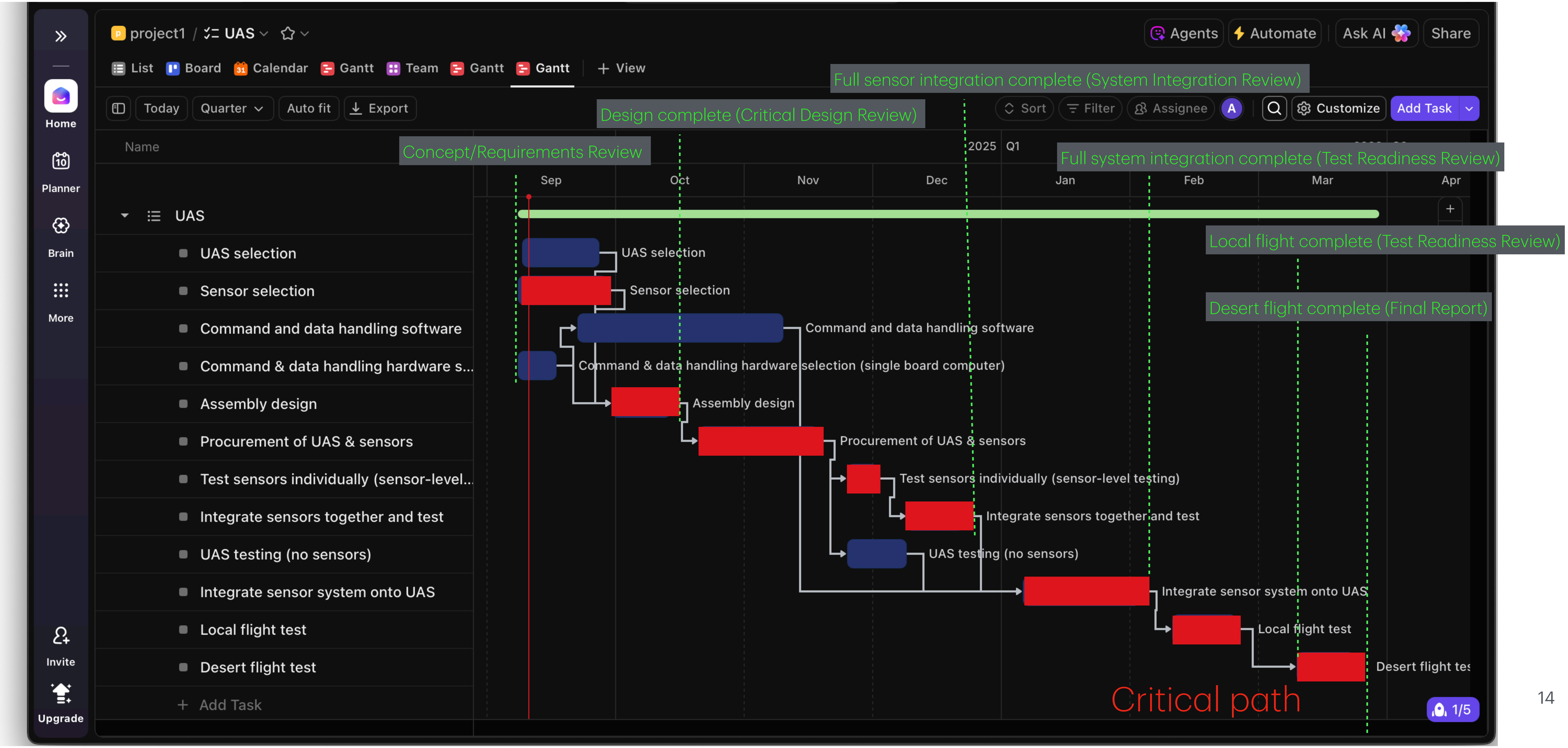
Back to UAS schedule



UAS schedule

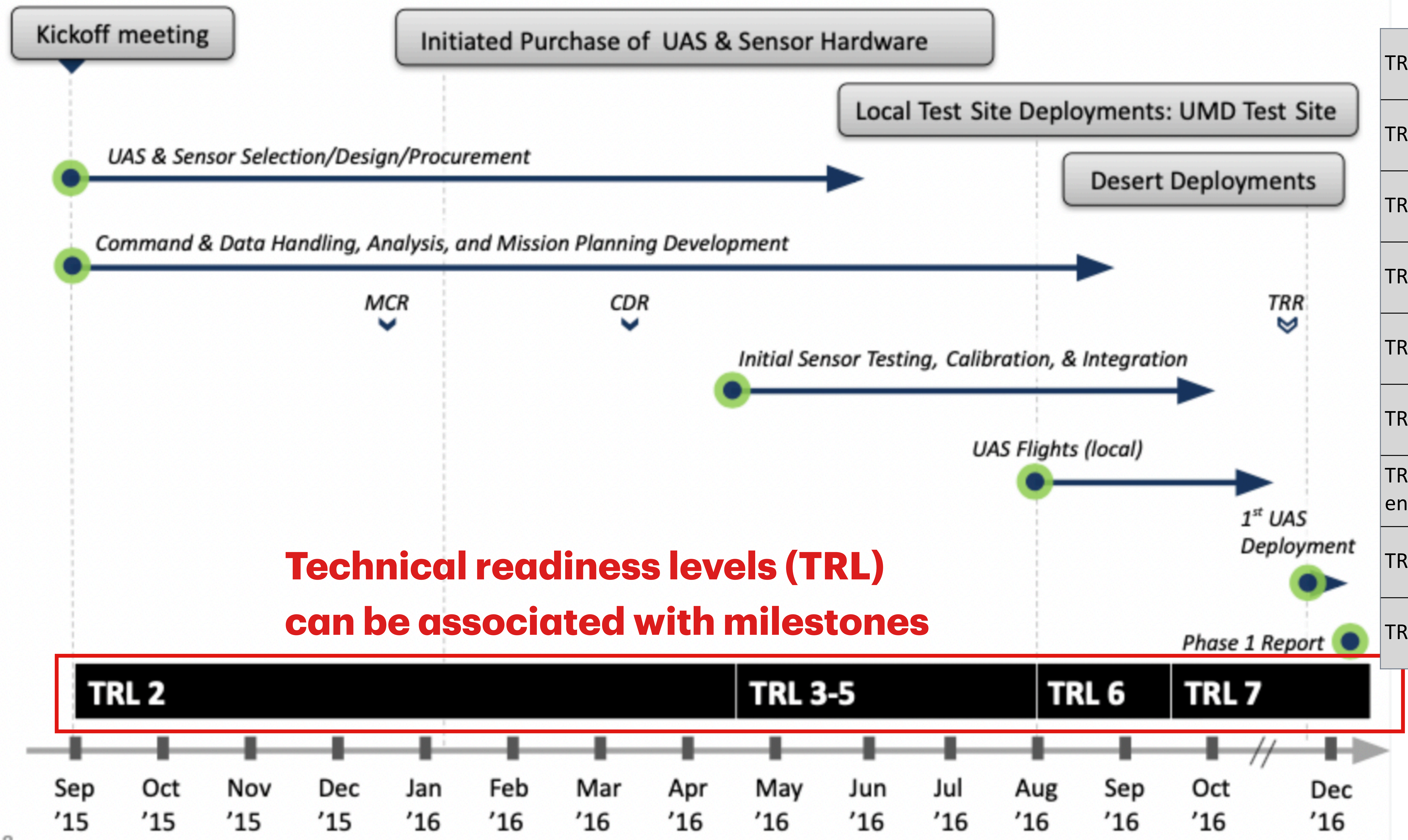


UAS schedule with milestones



GOES-R UAS Feasibility Demonstration Study Milestones & Schedule

Drafted & Submitted an initial set of near surface UAS science requirements to the NOAA Unmanned Aircraft Systems Program in January of 2015



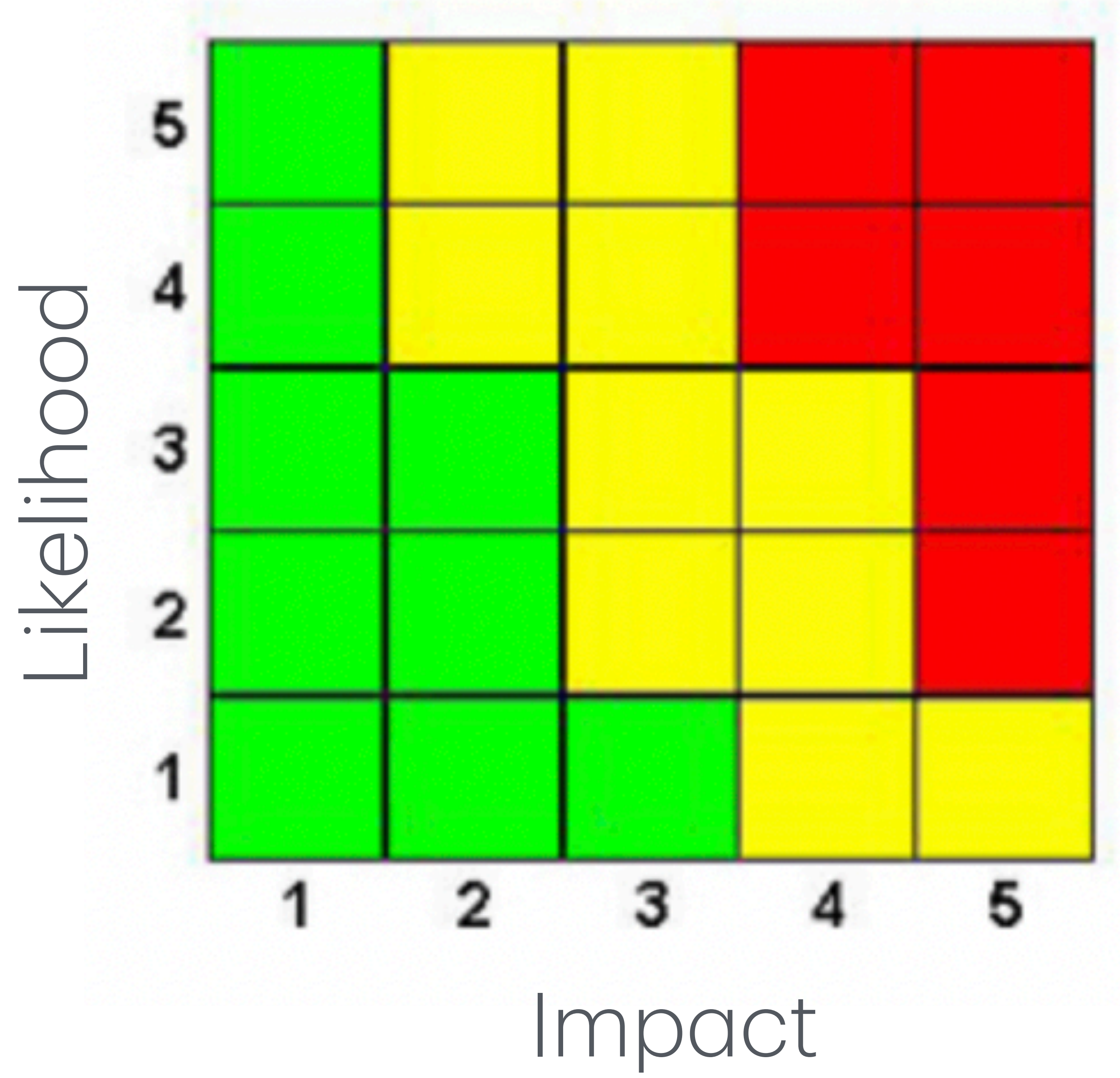
TRL 1: Basic principles observed
TRL 2: Technology concept formulated
TRL 3: Experimental proof of concept
TRL 4: Lab validation
TRL 5: Validation in relevant environment
TRL 6: Prototype demonstration
TRL 7: System prototype in operational environment
TRL 8: System completed & qualified
TRL 9: Actual system proven in operation

Risk management

- Risks: These are potential issues that could have a significant impact on the system performance, schedule, or safety

Basic steps for addressing:

- **Identify** - Review your system and look for potential issues that have a large impact on performance, schedule, safety
  - Example: Using a new sensing technology, where performance has not yet been verified
- **Classify**
  - Briefly describe
  - Assess likelihood (low, medium, high or 1-5)
  - Assess Impact (low, medium, high or 1-5)
- **Mitigate**
  - Describe mitigation steps: ex. Design redundancies, alternative parts, reallocation of resources



Risk description	Likelihood	Impact	Mitigation

Communication and leadership

- Establish clear communication channels - slack channel, weekly tag-ups
- Provide regular status updates, reviews, documentation including lessons learned
- Lead by enabling: Set the direction and allow group members to execute
- Build effective teams by listening to everyone's perspective

Wrap-up

- Project management provides a framework to effectively plan and execute a any project.
- Some key steps:
  - Formulate a clear objective (scope) for your project. Link the science objective with quantitative technical requirements
  - Propose a solution or system that can meet these requirements:
  - Breakdown all the physical and functional components
  - Link these components to tasks
  - Create a schedule, identify the critical path, and identify milestones; modify as project progresses
  - Identify, classify, and mitigate risks to performance, safety, or schedule
  - Communicate regularly, document progress, and lessons learned along the way

Homework

Create a preliminary schedule, identify the critical path, and identify several milestones for your project

- Note: You can use any software you choose to create a schedule: Excel, PowerPoint, ClickUp. Some other free ones are listed below (but I have never used them):

Free Project Management Tools (Beyond ClickUp)

- **TeamGantt** — User-friendly, visually appealing Gantt tool
- **GanttProject** — Offline, focused, simple; great for classroom use
- **Instagantt** — Sleek, online, integrates with Asana
- **Agantty** — Open-source, completely free
- **Zoho Projects** — Full-featured PM platform with Gantt timeline
- **Monday** — Flexible boards + timeline views, good UI
- **Smartsheet** — Familiar spreadsheet interface + visuals
- **Tom's Planner** — Simple, accessible Gantt for one-off projects

Due Sept 23, 2025

References

- https://www.nasa.gov/wp-content/uploads/2018/09/nasa_systems_engineering_handbook_0.pdf

Backup

Technology Readiness Levels (TRL) Definitions

TRL 1 Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.

TRL 2 Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.

Concept and lab validation

TRL 3 Analytical and experimental critical function and/or characteristic proof-of-concept: Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.

TRL 4 Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.

Relevant environmental testing

TRL 5 System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.

TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.

System demonstration and qualification

TRL 7 System prototyping demonstration in an operational environment (ground or space): System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.

TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space): End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.

TRL 9 Actual system "mission proven" through successful mission operations (ground or space): Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

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