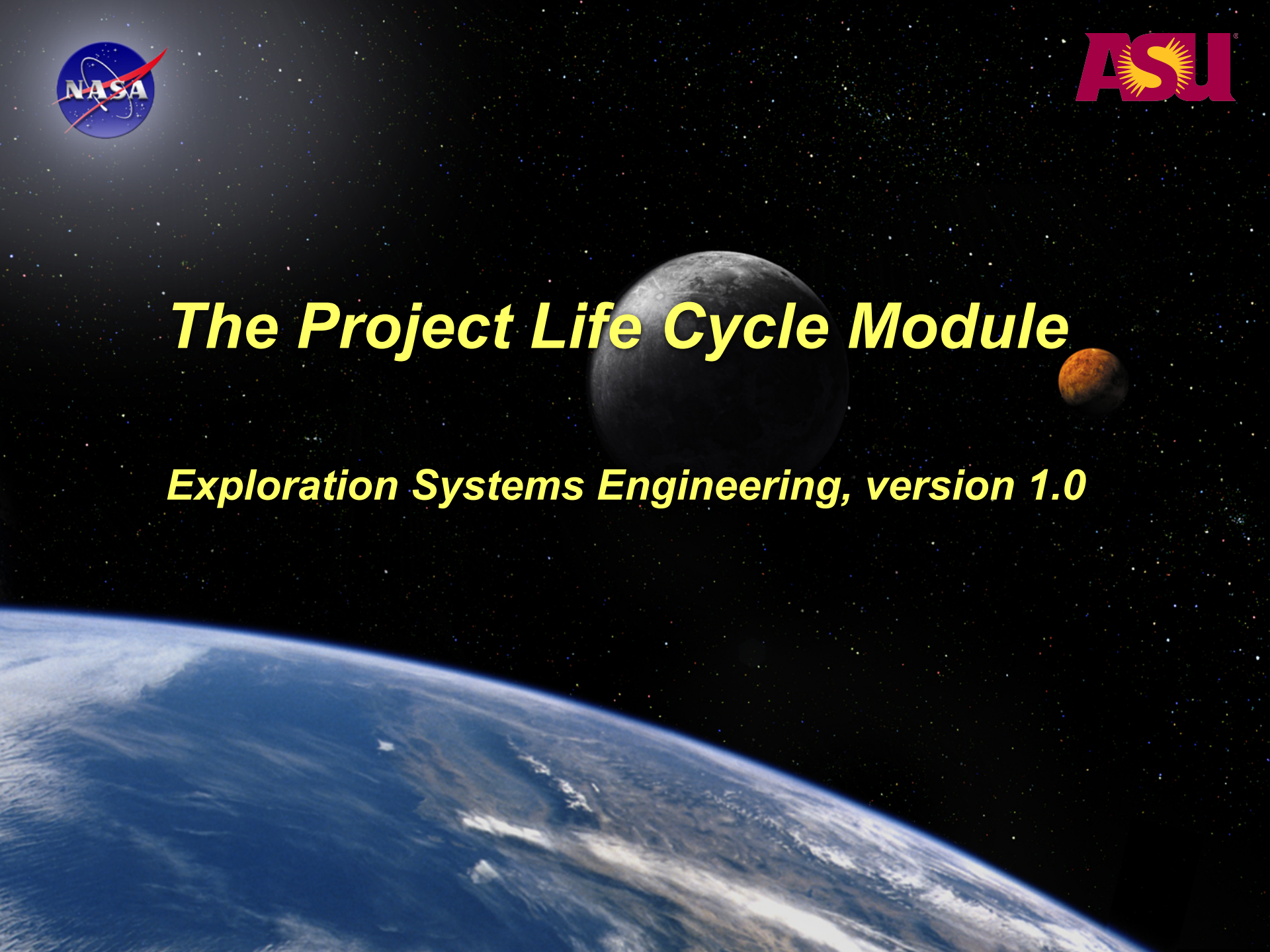

The Project Life Cycle Module
Exploration Systems Engineering, version 1.0

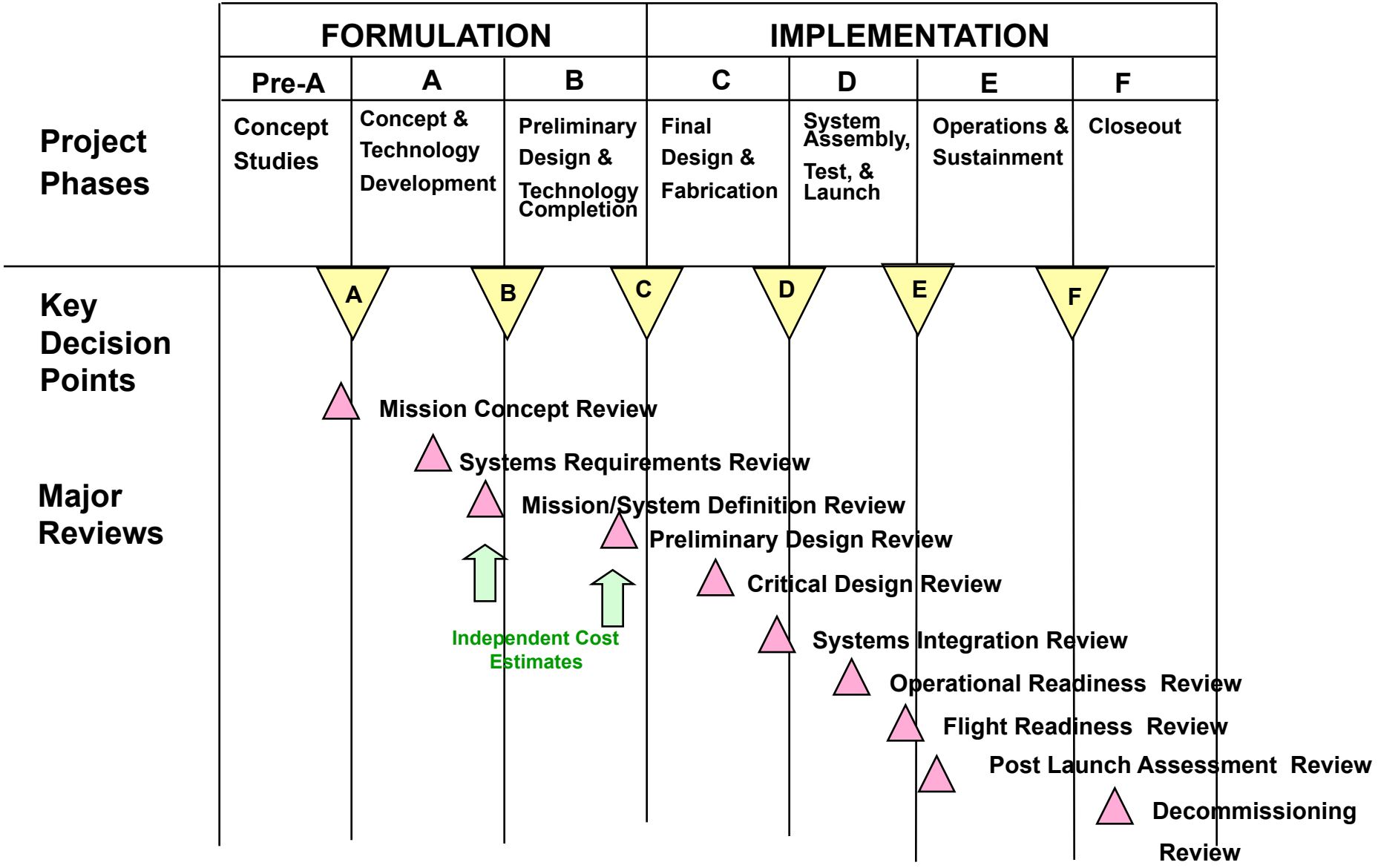
Module Purpose: The Project Life Cycle

- Describe the common project lifecycle phases, their purpose, activities, products and the review gates that separate them.
- Define what a system baseline is.
- Link project life cycle phases to the Vee systems engineering process model.
- Describe typical development times for each of the NASA project phases.

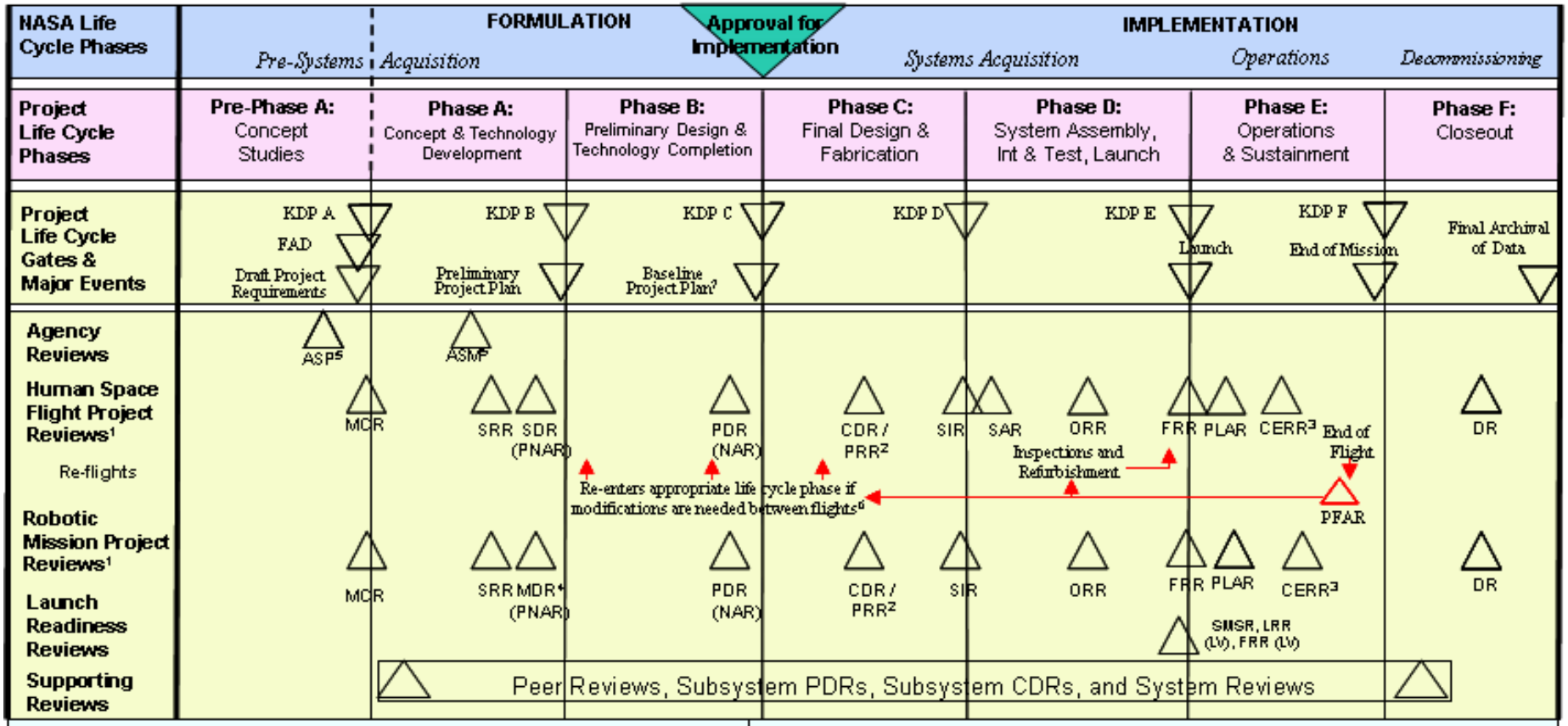
Introduction to the Project Life Cycle

- Lifecycle phases are used to help plan and manage all major aerospace system developments.
- Everything that should be done to accomplish a project is divided into distinct *phases*, separated by *control gates* that have to be passed to proceed.
  - For NASA the phases are lettered: Pre-Phase A, Phase A, Phase B, Phase C, Phase D, Phase E, Phase F
- Phase boundaries are defined at natural points for project progress assessment and *go/no go* decisions.
  - That is, should a project continue to the next phase, "go back to the drawing board" and redo some current phase work, or be terminated? The concern is that fact and not fantasy be presented at such reviews.
- Decomposing the project into life cycle phases organizes the development process into smaller more manageable pieces.
- Since early decisions commit later activities and more mature systems are harder to change, systems engineering done in the early phases has the greatest impact on mission success.

Major Project Reviews Precede Each Key Decision Point



Large Projects May Add Subsystem Reviews Before Their Corresponding System Reviews



FOOTNOTES

1. Flexibility is allowed in the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan. These reviews are conducted by the project for the independent SRB. See Section 2.5 and Table 2-6.
2. PRR needed for multiple (≥4) system copies. Timing is notional.
3. CERRs are established at the discretion of Program Offices.
4. For robotic missions, the SRR and the MDR may be combined.
5. The ASP and ASM are Agency reviews, not life-cycle reviews.
6. Includes recertification, as required.
7. Project Plans are baselined at KDP C and are reviewed and updated as required, to ensure project content, cost, and budget remain consistent.

ACRONYMS

ASP—Acquisition Strategy Planning Meeting
ASM—Acquisition Strategy Meeting
CDR—Critical Design Review
CERR—Critical Events Readiness Review
DR—Decommissioning Review
FAD—Formulation Authorization Document
FRR—Flight Readiness Review
KDP—Key Decision Point
LRR—Launch Readiness Review
MCR—Mission Concept Review
MDR—Mission Definition Review
NAR—Non-Advocate Review
ORR—Operational Readiness Review
PDR—Preliminary Design Review
PFAR—Post-Flight Assessment Review
PLAR—Post-Launch Assessment Review
PNAR—Preliminary Non-Advocate Review
PRR—Production Readiness Review
SAR—System Acceptance Review
SDR—System Definition Review
SIR—System Integration Review
SMSR—Safety and Mission Success Review
SRR—System Requirements Review

Each Milestone Review Creates A New System Baseline

- A 'baseline' is both a noun and a verb.
  - As a noun it is an agreed-to set of requirements, designs, or documents.
  - As a verb it is the process of establishing a baseline.

- In the context of a system review, a *baseline* is also defined as a complete system description, including requirements, designs, or documents that will have changes controlled through a formal approval and monitoring, or configuration management process.

- Since *baselines* capture the complete system description they are powerful tools in ensuring the entire team is working with the same requirements, designs, constraints, assumptions, interfaces, resource allocations and team responsibilities.

Project Life Cycle
Formulation Phases

- The project life-cycle *phases* of formulation and implementation are divided into incremental pieces. This allows the development team to access their progress, estimate system and project performance, plan the next phase and allows decision makers to assess management and technical progress.
- Formulation
  - Pre-Phase A (*Concept Studies)*
  - *Purpose: To produce a broad spectrum of ideas and alternatives for missions from which new projects can be selected.*
    - Define the mission needs, goals & objectives.
    - Perform studies of a broad range of mission concepts that contribute to goals and objectives.
    - Develop draft project-level requirements, operations concept, and potential technology needs.
    - Show that at least one mission concept can work.

Control Gate

=> Complete Mission Concept Review (MCR): review overall approaches as a baseline for Phase A.

Project Life Cycle
Formulation Phases, cont.

- Formulation
  - Phase A (*Concept & Technology Development*)
  - *Purpose: To determine the feasibility of a suggested new system in preparation for seeking funding.*
    - Define mission success, and minimum mission.
    - Perform trade studies to compare mission concept options.
    - Develop a baseline mission concept, including best technical approach, project execution, cost and schedule.
    - Complete the requirements to the subsystem level.
    - Identify requirements flow between and across subsystems.
    - Begin needed technology developments.

Control Gates

=> Complete System Requirements Review (SRR): Review requirements as baseline for final concept. Establishes the System Requirements baseline.

=> Complete System Definition Review (SDR/MDR): Review baseline for Phase B. Establishes the Functional baseline.

Project Life Cycle
Formulation Phases, cont.

- Formulation
  - Phase B (*Preliminary Design & Technology Completion*)
  - *Purpose: To define the project in enough detail to establish an initial baseline capable of meeting mission needs.*
    - Refine concept of operations.
    - Allocate functions and resources (e.g., mass margins).
    - Requirements: continue to refine; define flow to the box level; develop verification matrix.
    - Establish design solution that meets mission needs.
    - Demonstrate that technology development is complete.

    => Preliminary Design Review (PDR): Review requirements, design and operations as baseline for detailed design. Establishes the Allocated baseline, also known as the 'design-to' baseline.

Control Gates

=> Non-Advocate Review (NAR)/Confirmation Review:

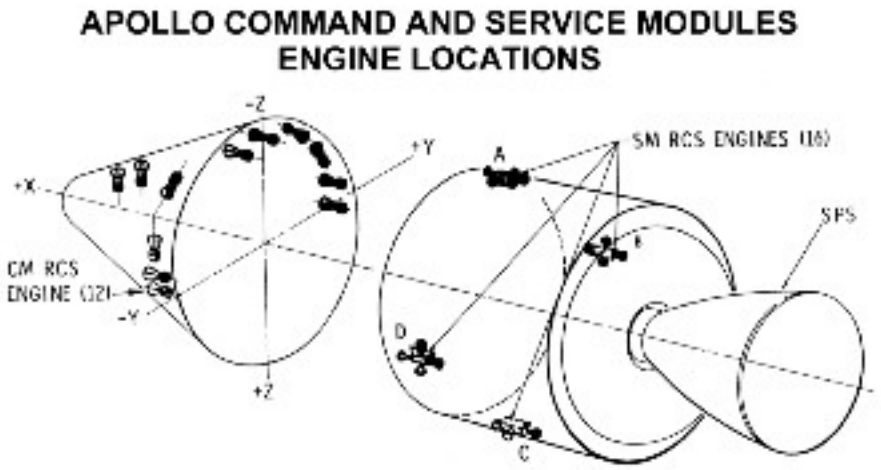
- Do the mission, spacecraft and instrument designs meet the mission/ science requirements?
- Are management processes sufficient to develop and operate the mission?
- Do cost estimates, control processes and schedule indicate that the mission will be ready to launch on time and within budget?

Project Life Cycle
Implementation Phases

- Implementation (NASA officially *commits* to the approved integrated baseline)
  - Phase C (*Final Design and Fabrication*)
  - *Purpose: To design a system (and its associated subsystems, including its operations systems) so that it will be able to meet its requirements.*
    - Demonstrate that the detailed system design meets requirements.
    - Demonstrate that the design drawings are complete.
    - Establishes the product baseline, also known as the 'build-to' baseline.
    - Begin fabrication of test and flight article components, assemblies, and subsystems.

Control Gate

=> Critical Design Review (CDR): Review design drawings and test plans.

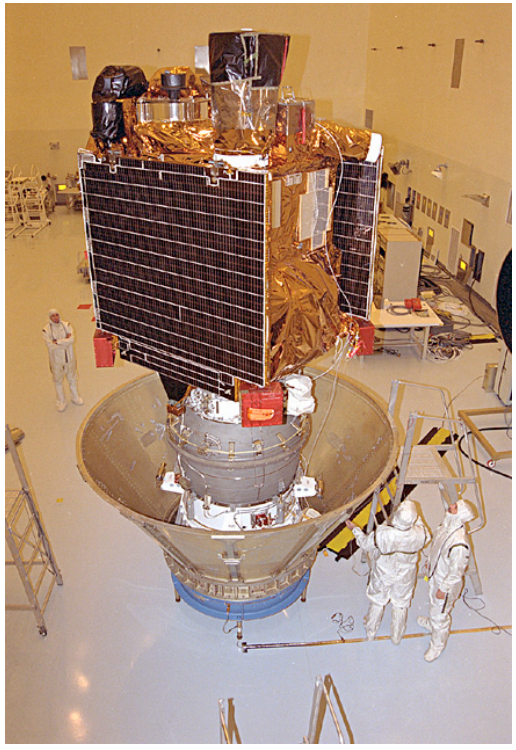


Project Life Cycle
Implementation Phases, cont.

- Phase D (*System Assembly, Integration and Test, and Launch*)
  - *Purpose: To build the subsystems (including operations systems) and integrate them to create the system, while developing confidence that it will be able to meet the systems requirements.*
    - Perform system assembly, integration, and test.
    - Verify system meets requirements.
    - Prepare system for deployment.
    - Launch system.
    - Verify deployment and operations.

Control Gate

=> Complete Flight Readiness Review (FRR): review system preparedness for launch. Establishes the 'As-built' baseline



Mars Global Surveyor during integration and test.

Project Life Cycle
Implementation Phases, cont.

Phase E (Operations and Sustainment)

- Purpose: To ensure that the certified system is ready for operations.
  - Implement the Mission Operations Plan developed in earlier phases.
  - Collect and archive mission and science data.

Control Gate

=> Complete Post Launch Assessment Review (PLAR): Review to assess readiness to proceed with full, routine operations. Establishes the Operational (or 'as-deployed') baseline.

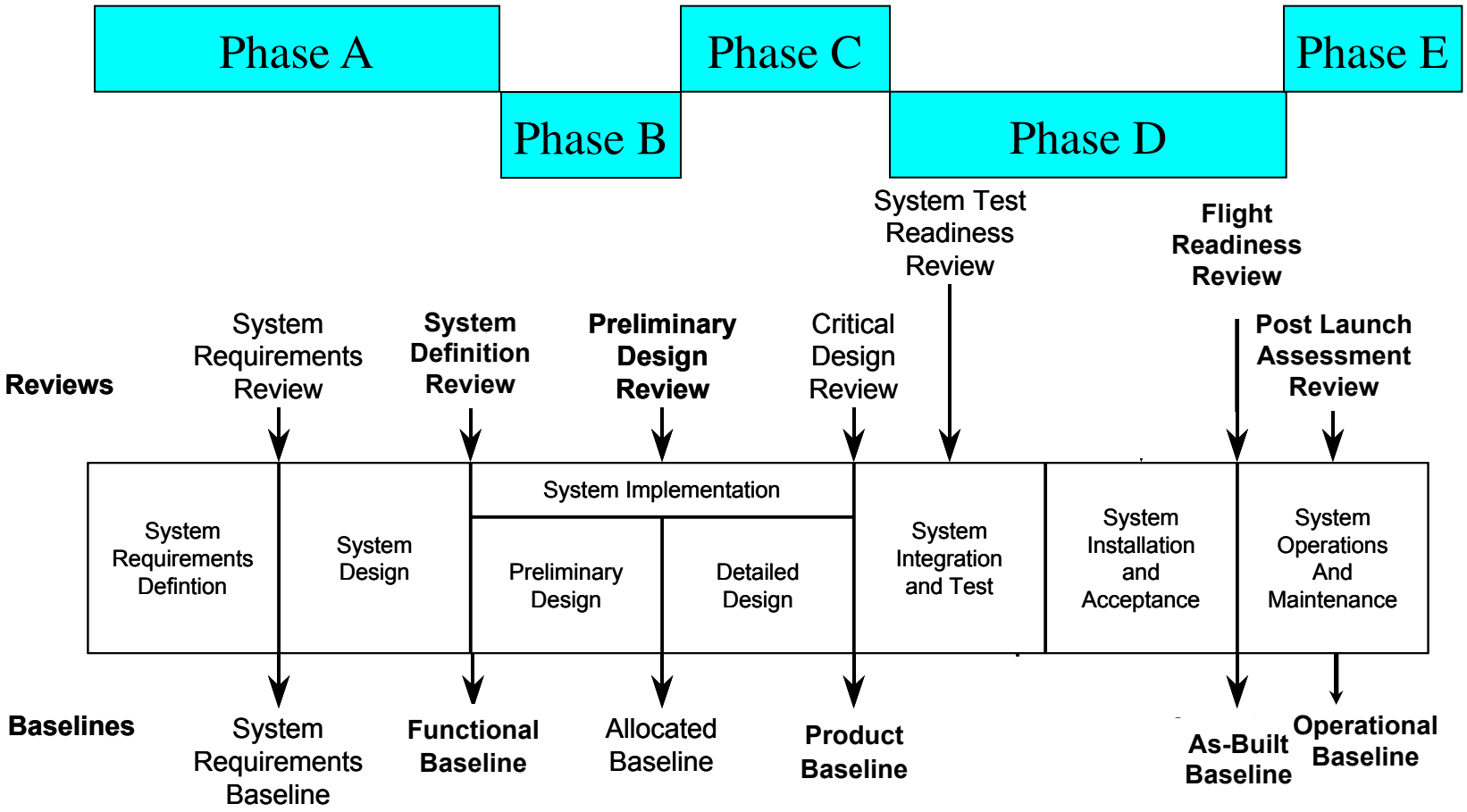
Phase F (Closeout)

- Purpose: To dispose of the system in a responsible manner.
  - Conduct a disposal review.
  - Implement the Systems Decommissioning/ Disposal Plan.
  - Perform analyses of the returned data and any returned samples.

Stardust Landing

Genesis Landing

Project Lifecycles - Incremental Development Phases Captured Via Baselines and Bounded by Technical Reviews

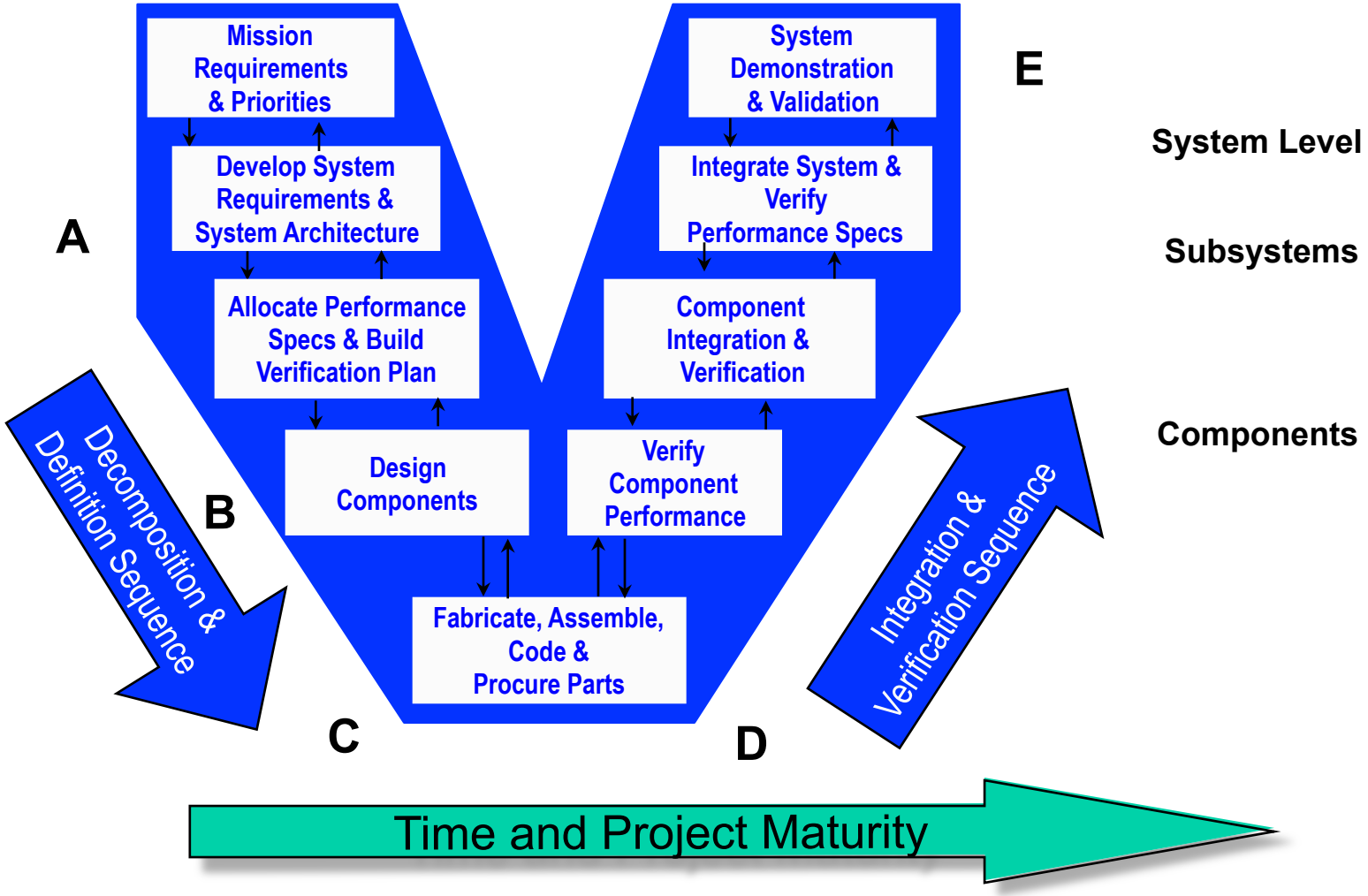


Need Specify Decompose Design Integrate Verify Operate Dispose

Technical Baseline Definitions

- **System Requirements Baseline (Phase A)**
  - The system requirements baseline is the approved system level functional and performance requirements.
  - Established at the System Requirements Review (SRR).
- **Functional Baseline (Phase A)**
  - The functional baseline is the approved documentation describing a system's functional, performance, and interface requirements and the verifications required to demonstrate achievement of those specified characteristics.
  - Established at the System Definition Review (SDR).
- **Allocated Baseline aka the 'Design-to' Baseline (Phase B)**
  - The allocated baseline extends the top-level performance requirements of the functional baseline to sufficient detail for initiating manufacturing or coding.
  - Established at the Preliminary Design Review (PDR).
- **Product Baseline aka the 'Build-to' Baseline (Phase C)**
  - The product baseline describes detailed form, fit, and function characteristics; the selected functional characteristics designated for production acceptance testing; the production acceptance test requirements.
  - Established at the Critical Design Review (CDR).
- **'As-Built' Baseline (Phase D)**
  - The as-built baseline describes the detailed form, fit, and function of the system as it was built.
  - Established at the Flight Readiness Review (FRR).
- **Operational Baseline aka 'As-Deployed' Baseline (Phase E)**
  - The as-deployed baseline occurs at the Operational Readiness Review (ORR) . At this point, the design is considered to be functional and ready for flight. All changes will have been incorporated into the final documentation.

The Engineering Activities in the Project Life Cycle



NASA Time Scales for Project Life Cycle

For a NASA Announcement of Opportunity (AO)-driven mission:

- The proposing team works Pre-Phase A in 1st round and
- Phase A in 2nd round (if they win). Lots of internal research & development (IRAD) dollars here.
- Official acceptance puts the mission/proposer into Phase B. Still has to go thru confirmation review to enter Phase C.

<u>AO Mission Types</u>

- Discovery Program example:
  - Phase A Concept Study - 7 months
  - Selection through launch ~ 7 years
- Mars Scout Program example:
  - Phase A Concept Study - 9 months
  - Selection through launch ~ 6 years
- Small Explorer Program example:
  - Phase A Concept Study - 3 months
  - Selection through launch ~ 3-4 years

For a facility-class telescope development, 10-15 years depending on technology development required.

For a human spacecraft development (Pre-phase A through Phase D/ Launch), on the order of 10-20+ years.

Pause and Learn Opportunity

Examine online the Defense Acquisition University (DAU) Wall chart - front & back (DAU_wallchart.pdf & DAU_WallchartBack.pdf).

Display the DAU life cycle wall charts in the classroom.

Compare the products, reviews and other aspects of the life cycle with the NASA version in the lecture module.

You can also refer to the Johnson Space Center version wall chart (PPF_WallChart_color.pdf) for comparison.

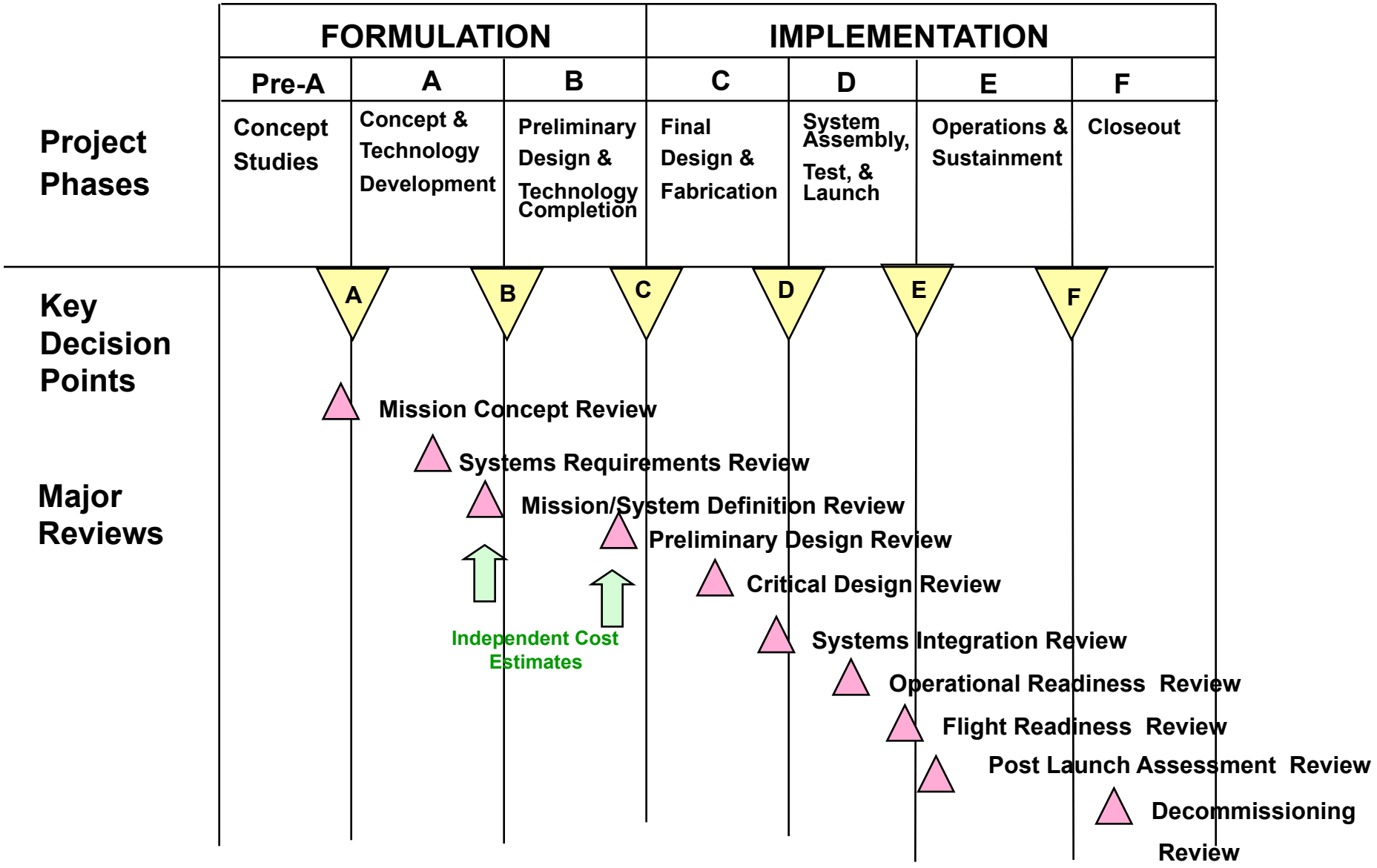
Alternatives to the Linear Project Life Cycle

- The development life cycle is dependent upon the technical nature of what's being developed => the project life cycle may need to be tailored accordingly.
  - Alternatives exist in industry and the government.
- Spiral development, often used in the software industry
  - Where the development and construction activities proceed in parallel; follows the doctrine of successive refinement.
- Rapid prototyping
  - Produces partially operational mock-ups/prototypes early in the design (initiated during preliminary design phase) to allow for learning prior to production of expensive flight unit.
- Skunkworks (Lockheed trademark)
  - "A skunkworks is a group of people who, in order to achieve unusual results, work on a project in a way that is outside the usual rules. A skunkworks is often a small team that assumes or is given responsibility for developing something in a short time with minimal management constraints. Typically, a skunkworks has a small number of members in order to reduce communications overhead. A skunkworks is sometimes used to spearhead a product design that thereafter will be developed according to the usual process."

Module Summary: The Project Life Cycle

- A project is divided into distinct life cycle *phases.*
  - Pre-Phase A: Concept studies
  - Phase A: Concept and technology development
  - Phase B: Preliminary design and technology completion
  - Phase C: Final design and fabrication
  - Phase D: System assembly, test and launch (otherwise known as panic mode)
  - Phase E: Operations and sustainment
  - Phase F: Closeout or disposal
- These phases are separated by *control gates* - typically associated with a major project review, such as preliminary design review (PDR).
- Each project phase has a distinct purpose and set of products.
- At the end of each phase a new system baseline — or an agreed-to set of requirements, designs, or documents — is established.
- A system baseline is the point of departure for the development work in each new phase.

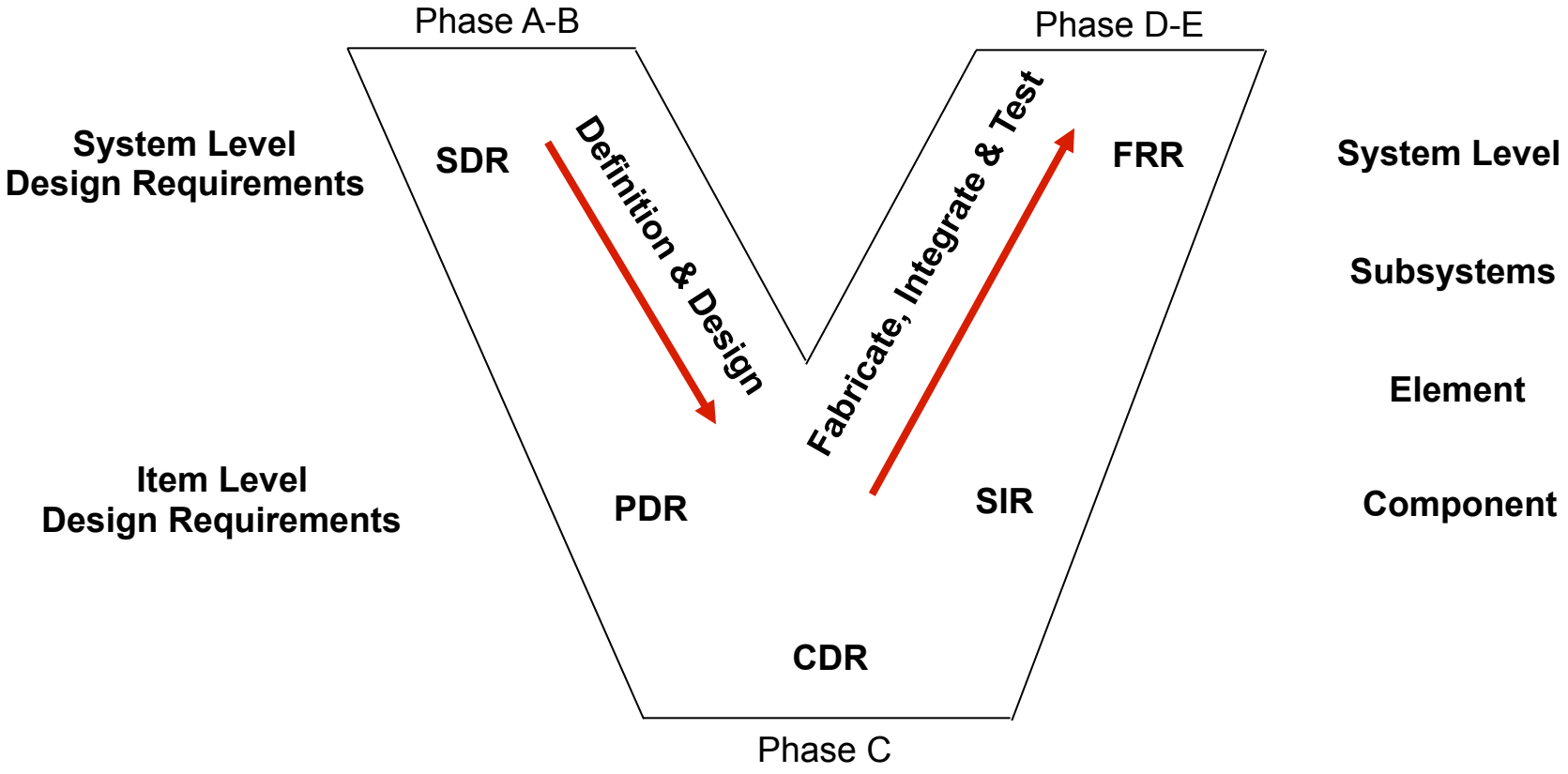
Major Project Reviews Precede Each Key Decision Point



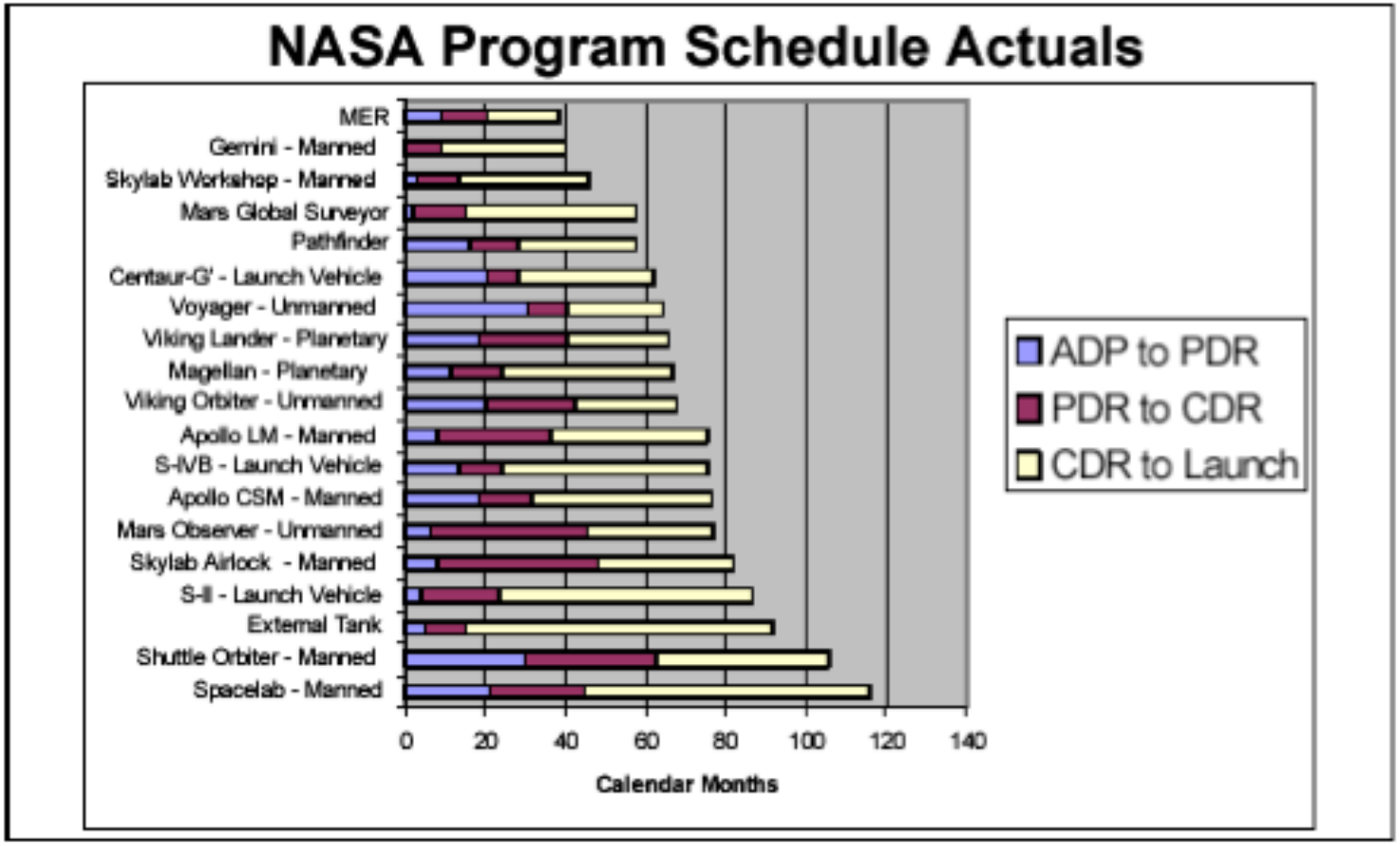
Backup Slides for Project Life Cycle Module

The Role of SE in the Project Life Cycle

Design is a top-down process while the Verification activity is a bottoms-up process. Components will be fabricated and tested prior to the subsystems. Subsystems will be fabricated and tested prior to the completed system.



NASA Project Development Times Vary Widely



ADP-PDR = Phase A/B; PDR-CDR = Phase C; CDR-Launch = Phase D

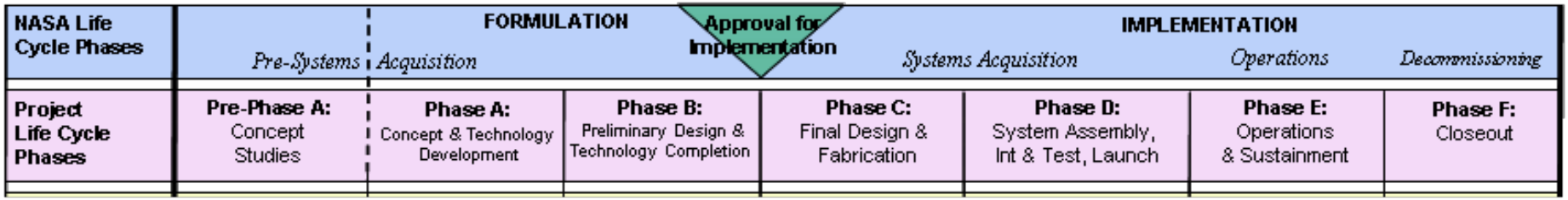
ADP = Advanced Development Plan

Historical Project Schedule Analysis (months)

	Example	Phase A	Phase B	Phase C	Fab	ATLO	Total
All Inherited Technology	MGS	3	3	6	5	9	26
New Engineering	Stardust, Genesis	5	7	10	6	12	40
New Technology	CloudSAT GRACE	6	8	10	9	12	45
Moderately Complex Payload with New Engineering	Magellan Odyssey Phoenix	7	7	12	9	15	48
Moderately Complex Payload with New Technology	Pathfinder, Deep Impact, MER	8	8	12	12	15	55
Highly Complex Payload with New Engineering	Mars Observer Voyager	7	7	18	24	22	78
Highly Complex Payload with New Technology	Galileo, Cassini, MSL	8	8	18	27	22	81

ATLO = Assembly, Test and Launch Operations

NASA Project Life Cycle



Key Definitions

- Formulation: The first part of the NASA management life cycle where system requirements are baselined, feasible concepts are determined, a system definition is baselined for the selected concept(s), and preparation is made for progressing to the Implementation Phase.
- Implementation: The part of the NASA management life cycle the detailed design of system products is completed and the products to be deployed are fabricated, assembled, integrated and tested; and the products are deployed to their customers or users for their assigned use or mission.

The Progression of Requirements Life Cycle Relationships