COLLEGE OF ENGINEERING
KEVIN T. CROFTON DEPARTMENT OF
AEROSPACE AND OCEAN ENGINEERING
VIRGINIA TECH.

Air Vehicle Design

AOE 4065 – 4066

III. Managing Air Vehicle Design Projects

Course Module P2

Project Organization

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AOE 4065-4066:
Capstone Air Vehicle Design (AVD) Course Modules (CMs)

Overview of AVD Courses

I. Foundational Elements

- F1. Design: *An Engineering Discipline*
- F2. Systems and Systems Thinking
- F3. Basics of Systems Engineering
- F4. Decision Making with Ethics and Integrity

II. Air Vehicle Design Fundamentals

- A1. Purpose & Process

Conceptual Design

- A2. Understand the Problem
- A3. Solve the Problem
- A4. Initial Sizing: *Takeoff Weight Estimation*
- A5. Initial Sizing: *Wing Loading and Thrust Loading Estimation*
- A6. Cost Considerations
- A7. Concept to Configuration: *Key Considerations*
- A7A. Configuration Layout: *Drawings & Loft*

Conceptual & Preliminary Design

- A8. Trade Studies
- A9. Use of Software Tools
- A10. Preliminary Design: *Baseline Design Refinement & Validation*

III. Project Management Topics

- P1. Basics of Project Management and Project Planning
- P2. Project Organization
- P3. Roles & Responsibilities of Team Members
- P4. Project Execution: *Teamwork for Success*
- P5. Project Risk Management
- P6. Delivering Effective Oral Presentations
- P7. Writing Effective Design Reports

Disclaimer

Prof. Pradeep Raj, Aerospace and Ocean Engineering, Virginia Tech, collected and compiled the material contained herein from publicly available sources solely for educational purposes.

Although a good-faith attempt is made to cite all sources of material, we regret any inadvertent omissions.

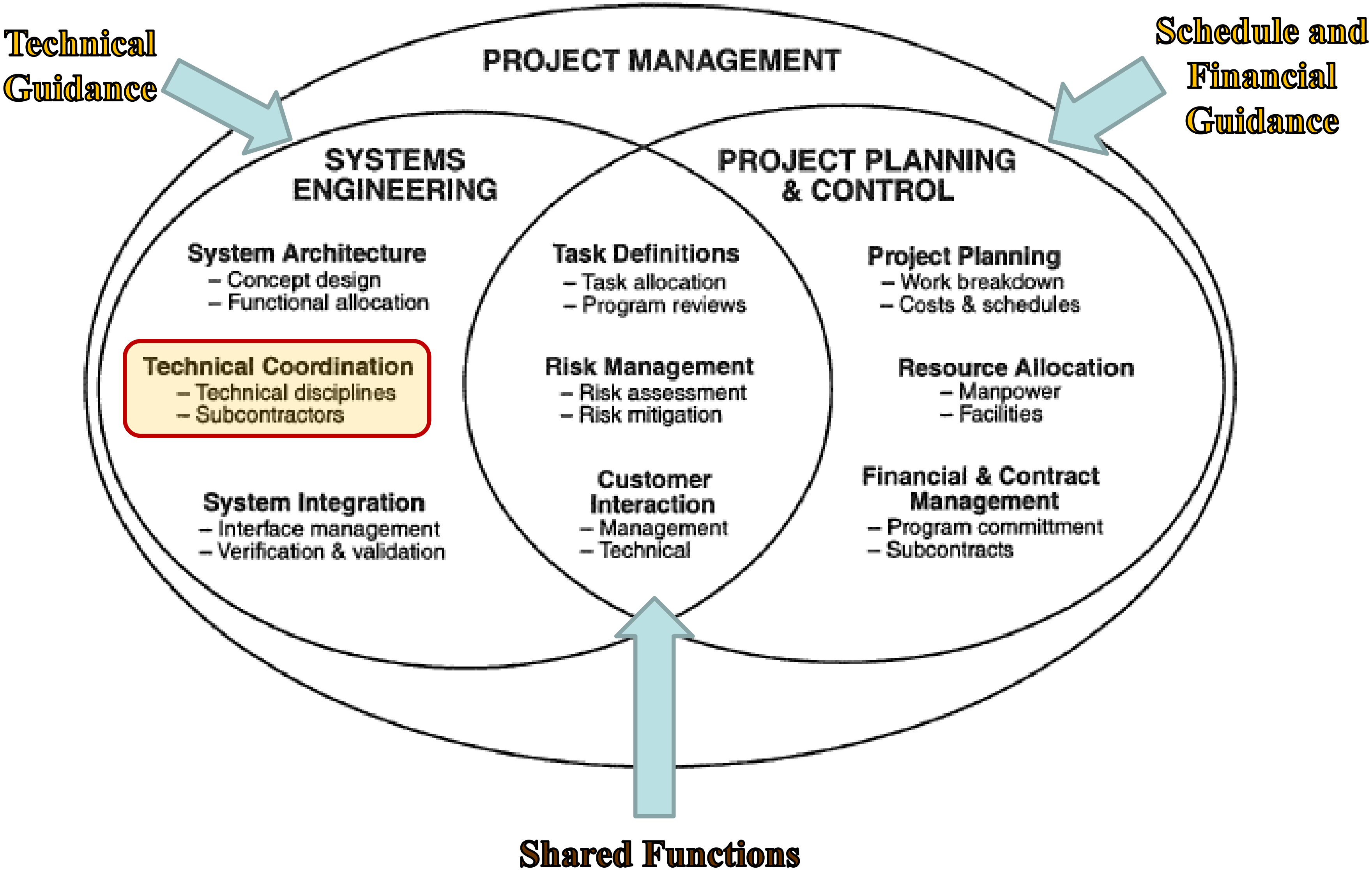
CRUCIALLY IMPORTANT

CMs only introduce key topics and highlight some important concepts and ideas…but without sufficient detail.

We must use lots of Reference Material* to add the necessary details!

(*see Appendix in the Overview CM)

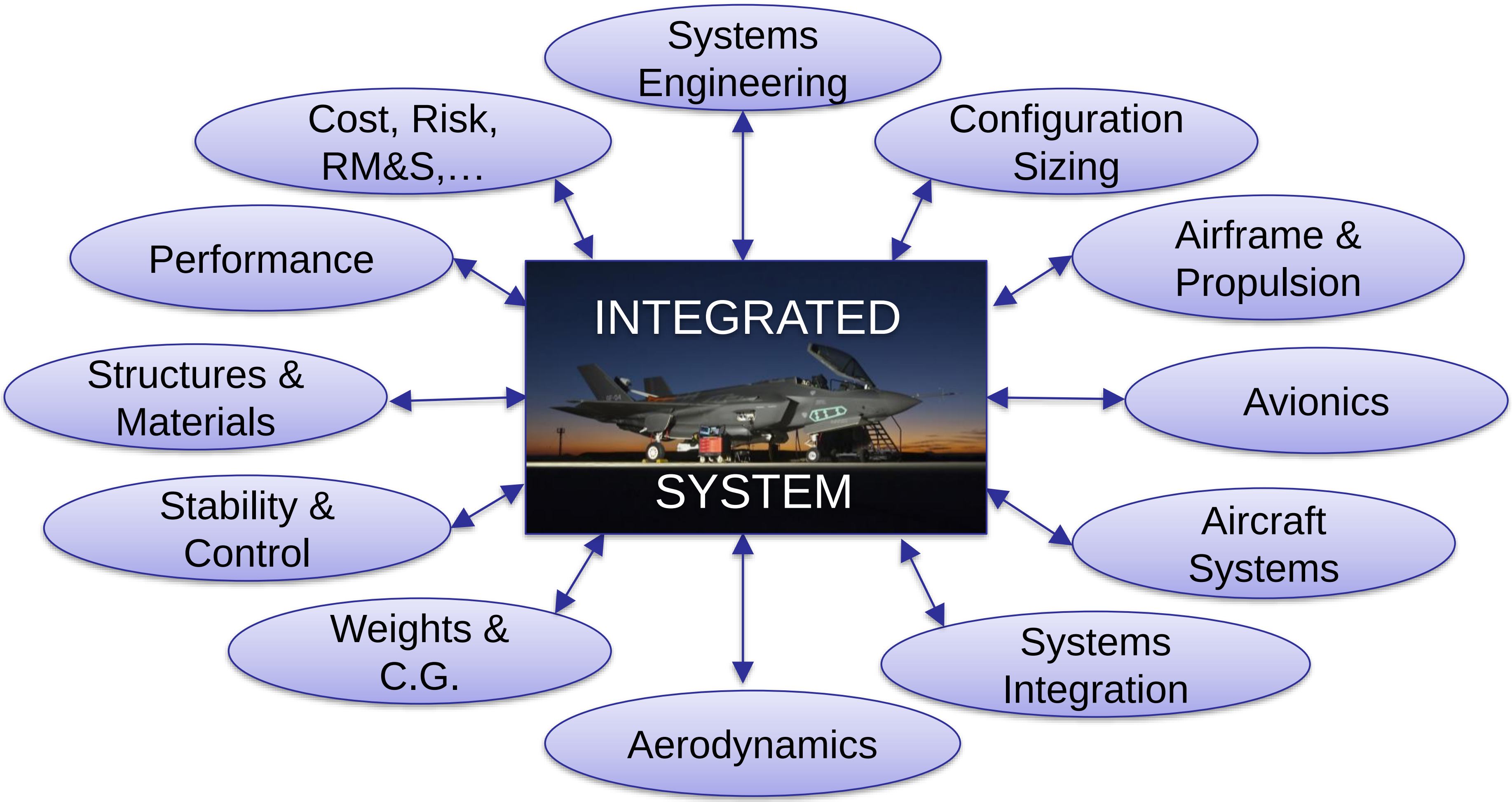
Project Organization:
An Essential Element of PM



Source: Fig. 4-1, Ref. SE 2 (Kossiakoff and Sweet); and Design of Projects Lectures by Bryan Moser (MIT)

Air Vehicle Engineering Design Project

Typical Contributing Disciplines



How to best organize the disciplines so that the engineering team can define and plan their work most efficiently and effectively to meet the scope, schedule and cost constraints of the entire project?

Organizing Technical Disciplines

Use a *N^2 Diagram,* a *NxN* matrix, to help arrange the order or sequence of disciplines to best leverage expertise and increase efficiency.

Constructing a N^2 Diagram

Geometry	Outer mold line	Nacelle configuration	Configuration	Engine locations	Wing area	Configuration design variables
	Structures			Structural weight		
Engine dimensions	Engine weight	**Propulsion**	Flight conditions		Engine data in flight envelope	Flight conditions
	Aerodynamic loading		**Aerodynamics**		Aero data in flight envelope	
				Weights	Aircraft weight in flight envel.	Take-off gross weight
					Mission Performance	Feasibility
Flight conditions	Configuration Variables					**Optimization**

Rules

1. Each box on diagonal represents discipline analysis
2. Execution of process starts at the top left and proceeds down diagonal
3. Data ***output*** from each analysis can be passed to the left or right of box
   a) Right – pass forward
   b) Left – pass back
4. Data ***input*** from other analyses can be passed in from above or below
   a) Above – pass forward
   b) Below – pass back

Courtesy of Dr. Darcy Allison

Constructing *Good* N^2 Diagrams

- **General rule: *Pass-forward* data relationships are *better* than *pass-back* data relationships**

- **Key considerations for improvements**
  - Efficient sequencing of individual disciplines
  - Providing missing data transfer links
  - Adding missing disciplines

- **Communication among disciplines**
  - Sets data relationships between disciplines
  - Document defining the “handshake” between disciplines

- **Accessible team document maintained by team lead**

Courtesy of Dr. Darcy Allison

An Improved N^2 Diagram

Propulsion	Engine dimensions	Flight conditions	Engine weight	Engine weight	Engine data in flight envelope	Flight conditions
Nacelle configuration	**Geometry**	Configuration	Outer mold line	Engine locations	Wing area	Configuration design variables
		Aerodynamics	Aerodynamic loading		Aero data in flight envelope	
			Structures	Structural weight		
				Weights	Aircraft weight in flight envel.	Take-off gross weight
					Mission Performance	Feasibility
Flight conditions	Configuration Variables					**Optimization**

What changed?

1. Moved propulsion earlier and structures later in the process to remove a pass-back data relationship
2. Moved structures after aerodynamics to remove a pass-back data relationship
3. Engine weight was not being passed to weights so added that
4. Any other changes? There are other arrangements that may or may not be better.

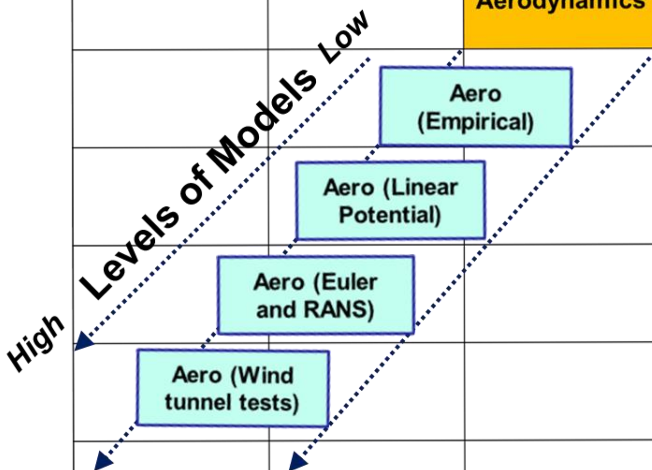
Courtesy of Dr. Darcy Allison

A Representative N² Diagram for Air Vehicle Design and Optimization

Geometry	Cowl and Inlet Shape	Outer Mold Line	Cowl, Aft Deck	Internal Str. Configuration	Mass Distribution	Wing Planform		Configuration
Flow behind Inlet Shocks	**Propulsion**	Bound. Layer Ingestion and Exhaust Flow	Engine Thermal Loads	Engine Mechanical Loads	Engine Weight and Location	Engine Deck		Thrust, Altitude, Mach #, BPR, etc.
		Aerodynamics	Skin Temp., Loading	Aero-Loads and Aeroelasticity		Polar in Flight Envelope		
			Thermal Management	EEWS Weight, Inertial Loads	EEWS Weight			
				Structures	Structural Weight – Other	Flexible Wing		
					Weights	Weight in Flight Envelope		Take-off Gross Weight
						Flight Performance		Feasibility
							Discipline X…	
Configuration	Thrust, Altitude, Mach#, BPR							**Optimization**

A Representative N^3 Diagram for Air Vehicle Design and Optimization

Geometry	Cowl and Inlet Shape	Outer Mold Line	Cowl, Aft Deck	Internal Struc. Configuration	Mass Distribution	Wing Planform		Configuration
Flow behind Inlet Shocks	**Propulsion**	Inlet and nozzle Flow	Engine Thermal Loads	Engine Mechanical Loads	Engine Weight and Location	Engine Deck		Thrust, Altitude, Mach #, BPR, etc.
		Aerodynamics	Skin Temp., Loading	Airloads and Aeroelasticity		Polars in Flight Envelope		Response surface model
			Thermal Management	EEWS Weight, Inertial Loads	EEWS Weight			
				Structures	Structural Weight – Other	Flexible Wing		Response surface model
					Weights	Weight in Flight Envelope		Take-off Gross Weight
						Flight Performance		Feasibility
							Discipline X…	
Configuration	Thrust, Altitude, Mach#, BPR							**Optimization**



All disciplines need not use the same level of modeling; appropriate levels may be selected for each as illustrated for Aerodynamics here.

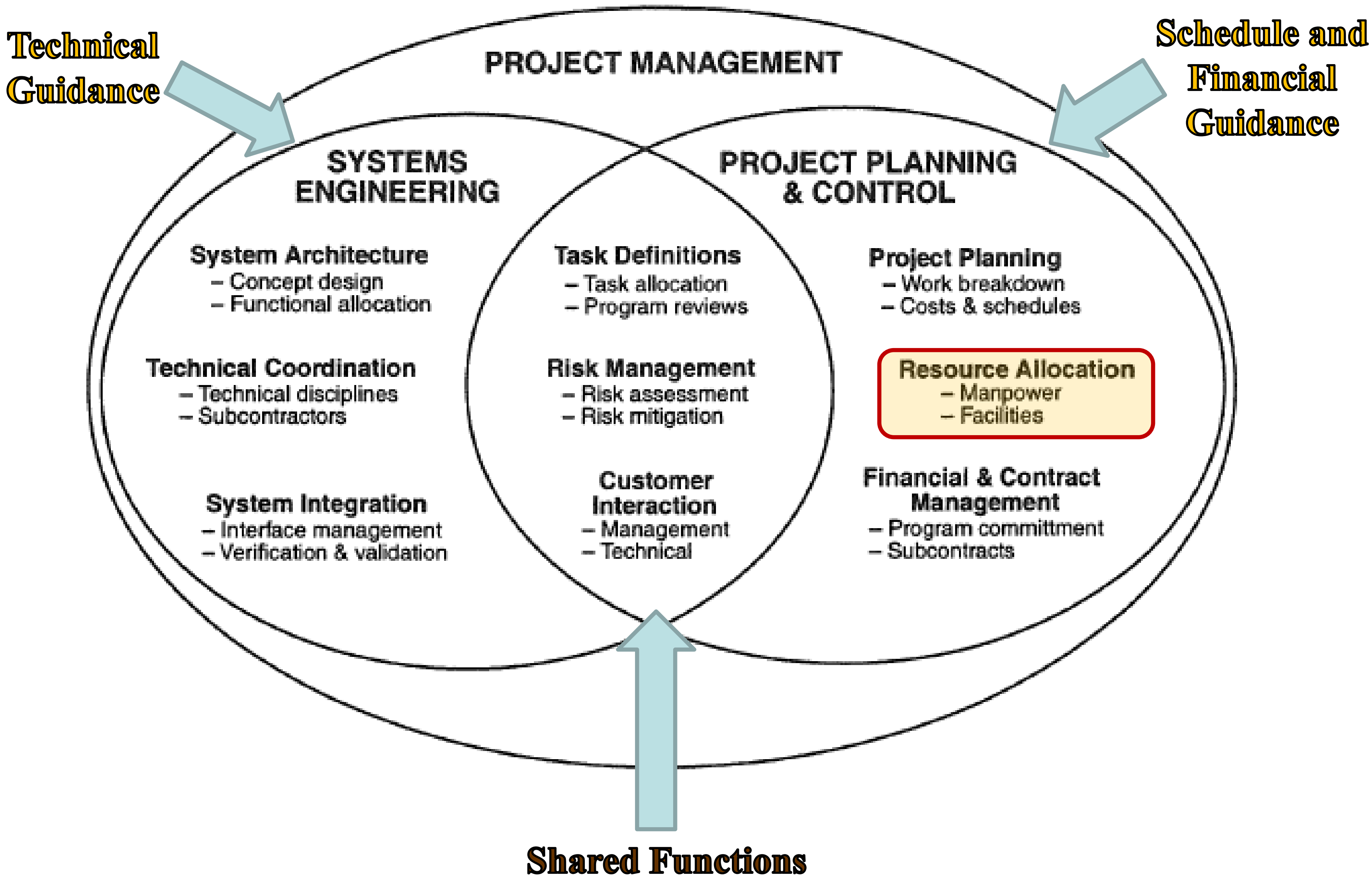
Outline

P2. Project Organization

P2.1 Organizing Technical Disciplines

P2.2 Organizing People

Project Organization:
An Essential Element of PM



Source: Fig. 4-1, Ref. SE 2 (Kossiakoff and Sweet); and Design of Projects Lectures by Bryan Moser (MIT)

Organizing People

- **Purpose**
  - **To clearly allocate responsibility and authority for different functions and activities to personnel with the right expertise.**

- **Three Types of Organizational Constructs**
  1. Dedicated (‘Projectized’)
  2. Functional
  3. Matrix

- **Integrated Product Teams (IPTs)**

Project Management is Really ALL about Leading People to Do Their Best--and More!

1. Dedicated Organization

Executive Management

- Project* A (Bomber)
  - Engineering
  - Test & Evaluation
  - Manufacturing
  - Finance
  - Contracts
  - …
- Project* B (Transport)
  - Engineering
  - Test & Evaluation
  - Manufacturing
  - Finance
  - Contracts
  - …

Pros

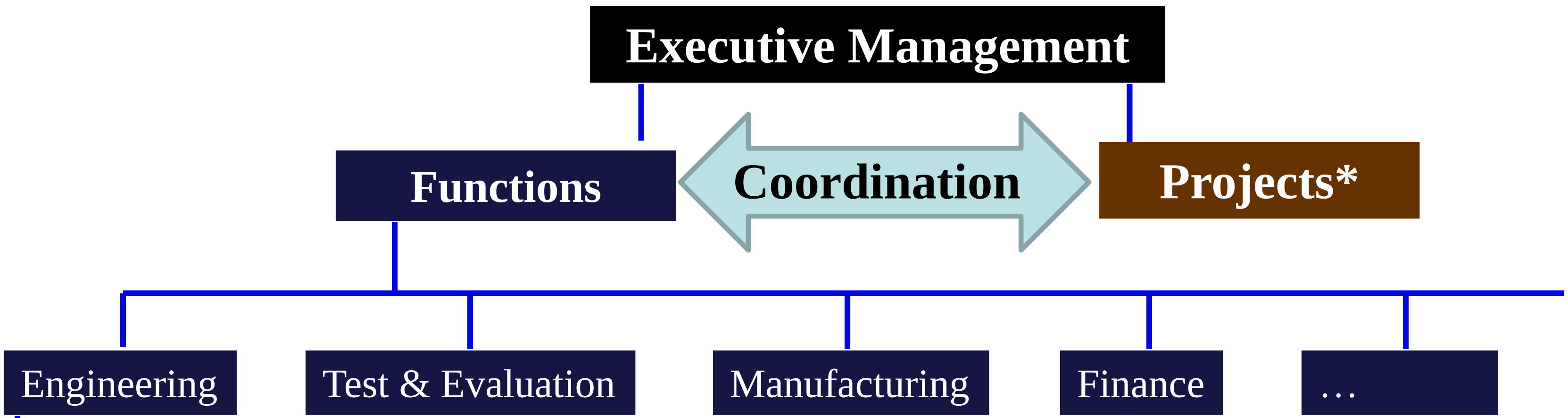
- Clear line of authority
- Effective "360" communication—both internal and with customers
- Fast Decision-making

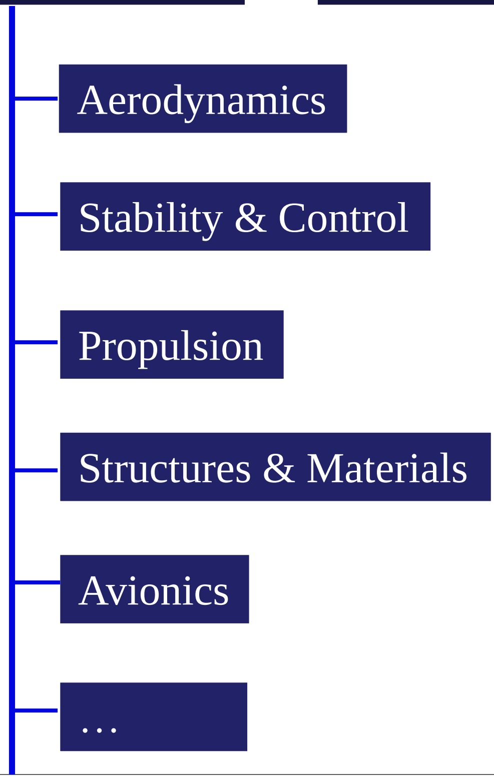
Cons

- Duplicated resources
- Poor disciplinary knowledge sharing
- Less flexibility to manage uncertainties
- Employees feel "stuck"

***Major Projects usually called Programs**

2. Functional Organization





Pros

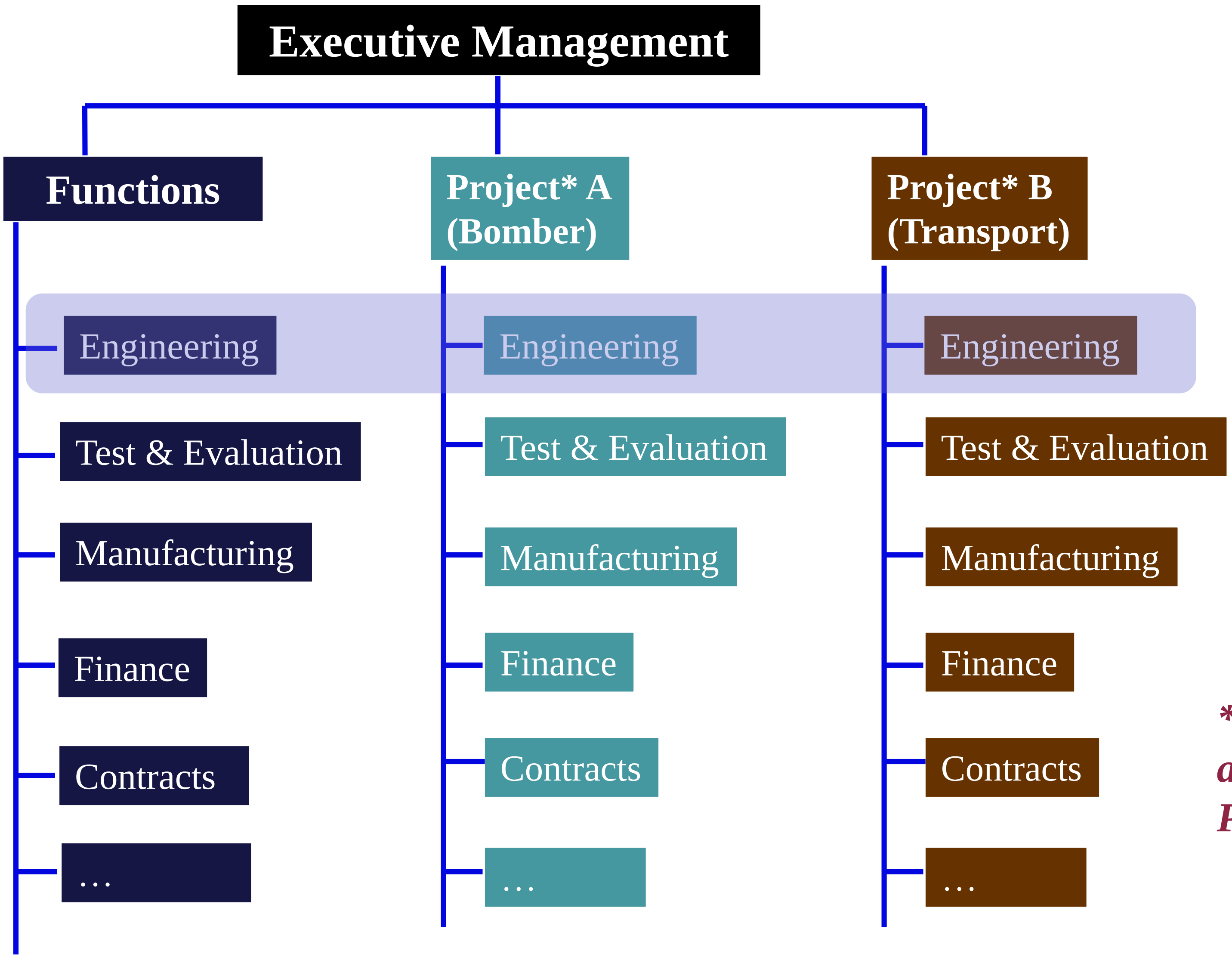
- Experienced managers guide personnel
- Opportunities for advancement
- Knowledge sharing within each discipline

Cons

- "Stovepipe" mentality
- Individuals support multiple projects
- Poor "360" communication
- Internal focus rather than Customer focus

Major Projects usually called Programs

3. Matrix Organization



**Major Projects are usually called Programs*

Functional Management Assigns Personnel and Tools to ALL Projects

Matrix Organization

Pros

- Skills and expertise shared most effectively
- Facilitates effective "360" communication—both internal and external
- Environment conducive to professional development
- More efficient use of available resources

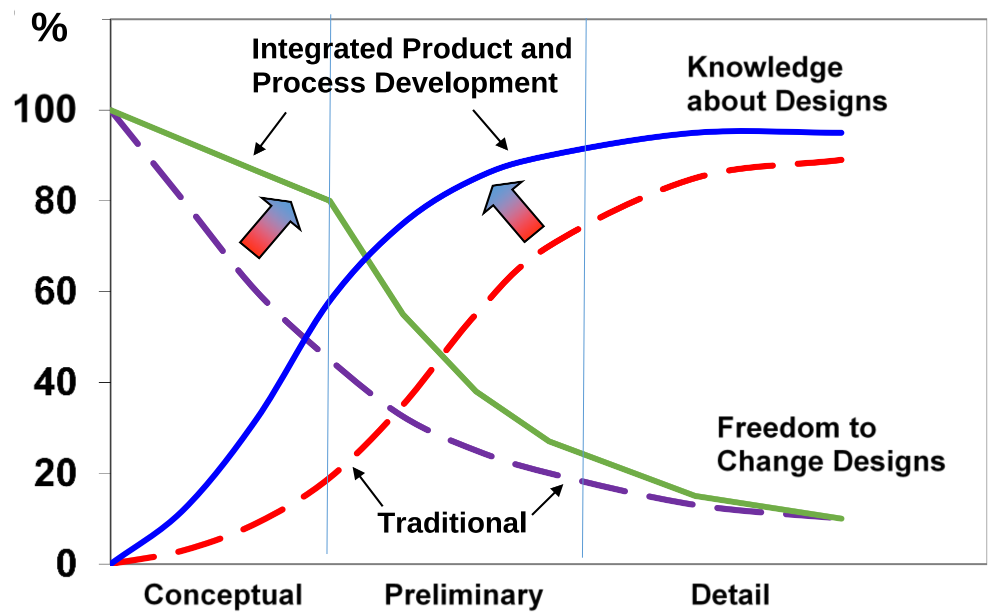
Cons

- Two (or more) bosses!
- Potential conflicts in assigning personnel and allocating resources to multiple projects
- Confused employees if roles and responsibilities not clearly delineated

Success Depends on
Clear Communication and Extensive Coordination

Integrated Product Teams (IPTs)

- **Popular since 1990s**
- **Driven by *Integrated Product and Process Development (IPPD)* philosophy**
- **Especially well-suited for complex systems development**
- **Multi-functional team of specialists—IPTs—working "as one"**
- **IPTs aren't "permanent"**
    - **Formed and disbanded as needed**

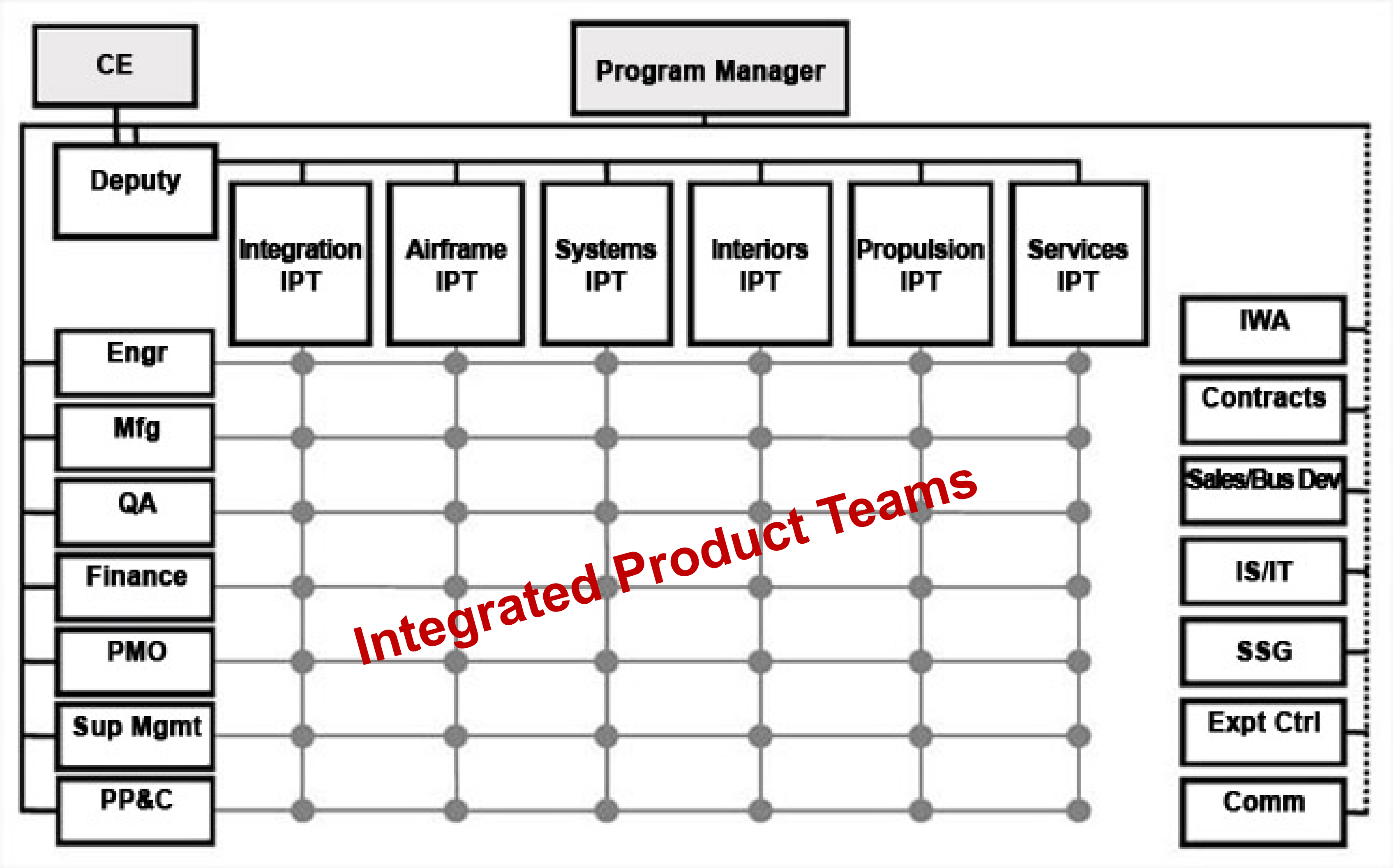


IPPD

- Consider All Requirements and Constraints from the Start
- Make Proper Tradeoffs in Early Stages of Design
- Implement using IPTs (Integrated Product Teams

Compress Time, Decrease Cost, Reduce Risk

Project Structure with IPTs

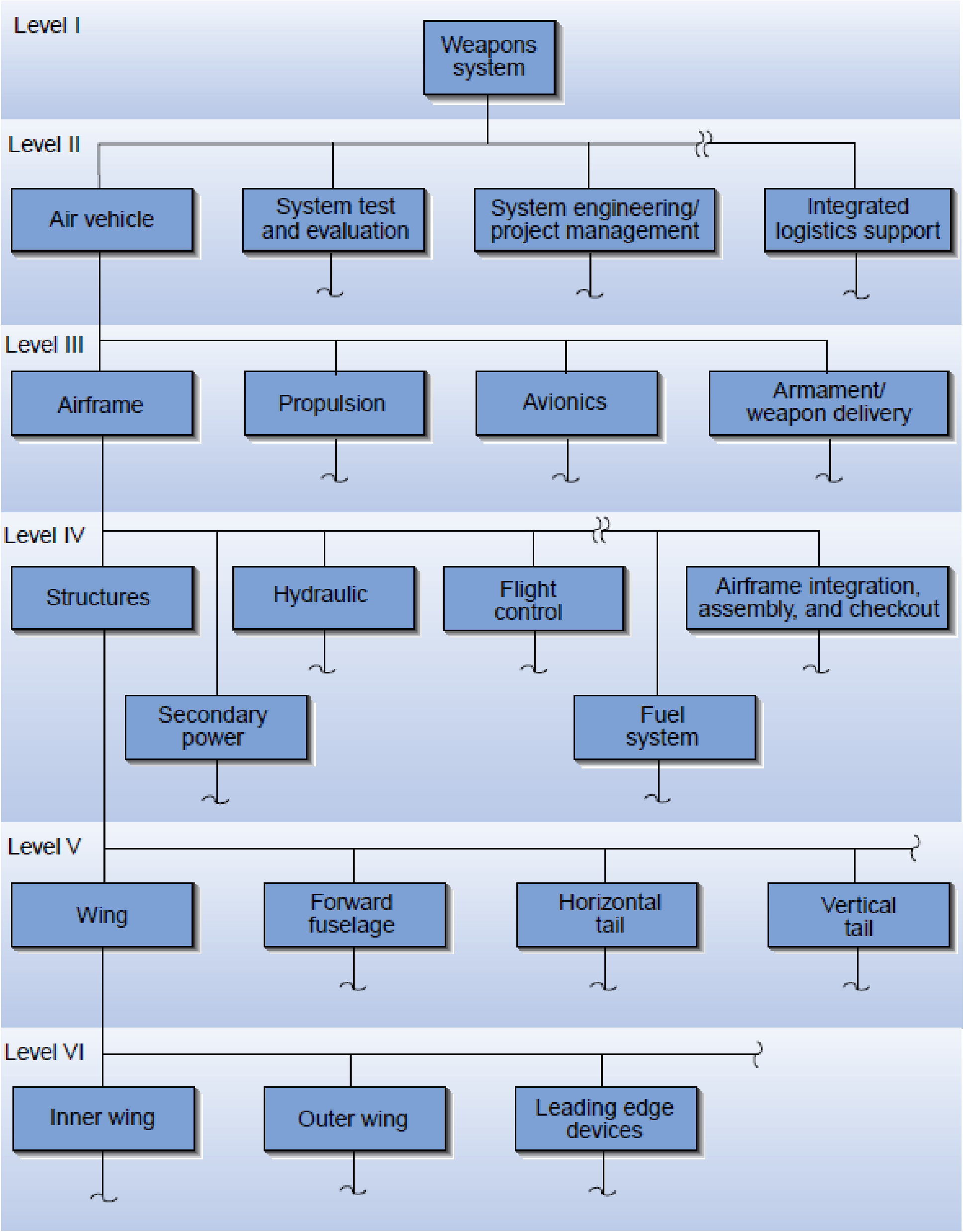


Driven by Integrated Product and Process Development (IPPD) Management Philosophy

F/A-18 IPT Example

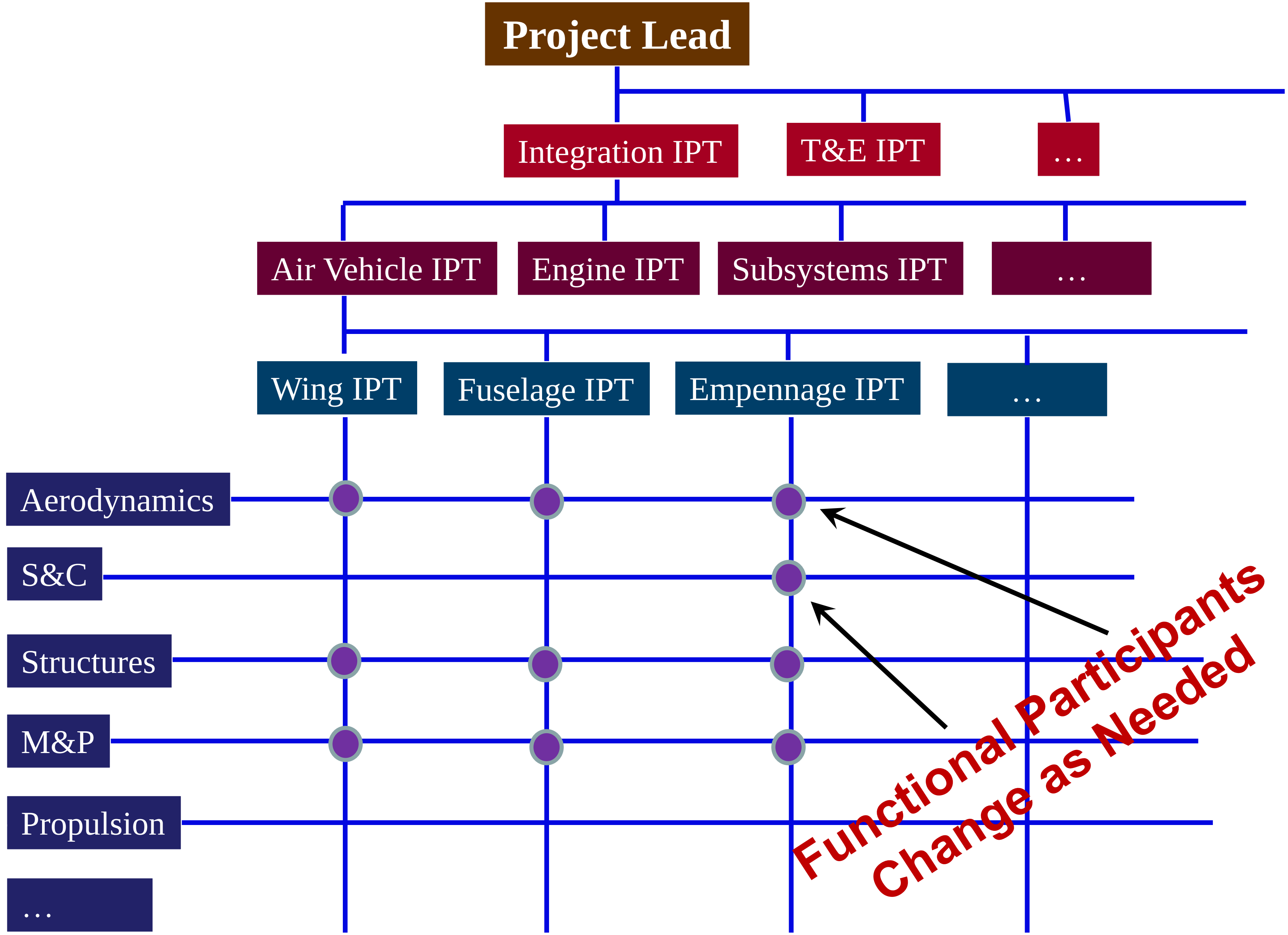
- **Focus on Products**
- **Multidisciplinary Teams of Specialists**
- **Systematically integrate inputs from all contributing disciplinary experts**
- **Concurrently consider and address all aspects**

Rapid Product Development through Improved Quality, Productivity, and Production Flexibility



Source: White, J.W., "Application of New Management Concepts to the Development of F/A-18 Aircraft," Johns Hopkins APL Technical Digest, Vol. 18, No. 1, 1997.

Notional IPT-based Org Chart

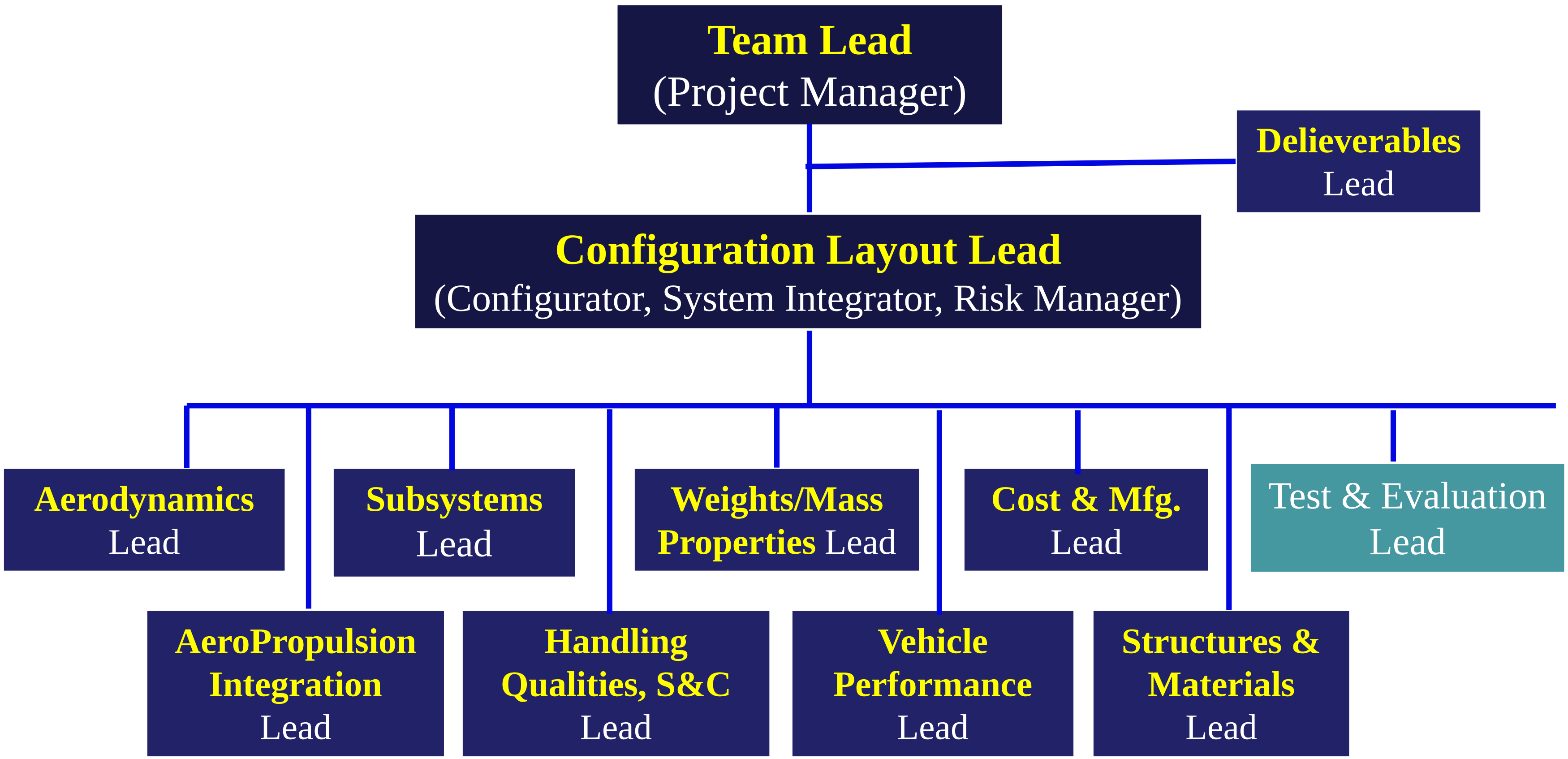


Typical Capstone Design Project: *Work Performed by a Multidisciplinary Team*

Sub-teams of student(s) are formed in a project multidisciplinary team to perform tasks in several areas including

1. **System Integration**—To ensure that final design meets *all requirements* and *MoMs*
2. **Systems Engineering**—Requirements, ConOps, MoMs, Design Drivers, Technology, Risk, Design Guidelines with "-ilities" (reliability, maintainability, supportability, etc.), functional and physical architectures, …
3. **Sizing**—TOGW, wing size, engine(s), carpet plots, constraint plots, trade studies, …
4. **Geometry**—Sketches, 3-view drawings, outer mold line (OML), interior arrangement,…
5. **Weights**—Component & subsystem & system weights, C.G., moment of inertias,…
6. **Performance**—Estimation and validation that vehicle meets mission requirements,…
7. **Aerodynamics**—Aerodynamic efficiency; forces and moments; high-lift devices, …
8. **Stability & Control**—Static margin, tail sizing, control surface sizing, c.g. excursions, …
9. **Propulsion**—Engine selection, nacelles, flow path (inlet, nozzle), propellers, …
10. **Structures & Materials**—Materials selection, load paths, critical loads (V-n diagram), operational limits,…
11. **Aircraft Systems**—Avionics, landing gear, payload (passenger, cargo), fuel tanks, actuators, environmental control system (ECS), electrical power, hydraulics, pneumatics,…
12. **Cost and Manufacturing**—Flyaway cost, life cycle cost (LCC), DOC, …
13. **Project Management**—Planning and execution of tasks on time, on budget
14. **Communication**—oral presentations and final report (in proposal style)

Typical Capstone Design Project “Org Chart”



Complete the Org Chart by adding names of the Leads (and of the Other Members, if any) to the respective boxes

What do these people actually do? See the R&Rs CM

Your Next Step

- **Plan and Organize your project**
- **Use N^2 diagram to make your multidisciplinary project team more efficient and productive**
  - All discipline representatives have full visibility of the entire multidisciplinary design process
  - Everyone can easily see how individual discipline fits into the "big picture"
  - It's a *Living Document*
    - Changes can be incorporated quickly
    - Changes have full team buy-in (no surprises)
  - Each box can be tested and validated individually using data for an existing aircraft design
    - Take defined data relationships
    - Get required input data from known validation aircraft
    - Compare discipline output with known validation aircraft
- **Maintain Configuration Control**
  - Team lead should be the only one allowed to make changes after full team discussion of proposed changes *("Too many cooks…")*