F-35A F-35B F-35C

A METHODOLOGY FOR ASSESSING U. S. DEFENSE SYSTEMS AFFORDABILITY MATURITY

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INCOSE, North Texas Chapter Meeting

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Agenda

- **What Does Affordability Mean to Customer vs. Developer?**
- **Complexity is Affordability Challenge**
- **A Method for Assessing Affordability Maturity of Defense Systems Development**
- **What Does It Take to Meet Cost and Schedule?**
- **Enablers**
- **Q&A**

The U. S. DoD Defines Affordability as

… the degree to which the life-cycle cost of an acquisition program is in consonance with the long-range investment and force structure plans of the Department of Defense or individual DOD Components. Affordability procedures establish the basis for fostering greater program stability through the assessment of program affordability and the determination of affordability constraints.

- Components shall plan programs consistent with the DOD Strategic Plan, and based on realistic projections of likely funding available in the future years
- **Affordability shall be assessed at each milestone decision point beginning with program initiation-usually-MILESTONE 1.**
- Cost Analysis Improvement Group (CAIG) reviews shall be used to ensure cost data of sufficient accuracy is available to support reasonable judgments on affordability for ACAT 1 programs.
- DOD Component Heads shall consult with the USD (A&T) or the ASD (C3I), as appropriate, on program objective memoranda (POM) and budget estimate submissions (BES) that contain a significant change in funding for, or reflect a significant funding change in, any program subject to review by the DAB or the DOD Chief Information Officer.

How is it being assessed today?

How Is Affordability Being Assessed Today?

Customer:

Are we acquiring what we *needed* for the *$* we paid within the *time* we agreed?

Affordability ≅

Cost, Schedule, and Technical Performances

(CPI, SPI, and TPM metrics)

Developer:

Are we delivering the *intended capabilities* within *cost* and *schedule* targets?

What are the basis for affordability assessment?

The Basis of Affordability

Cost Data {*past programs*}

Contractor {*past performances*}

Technology {*projection*}

Cost of Money {*projection*}

.
.
.

Estimation {*degree of accuracy*}

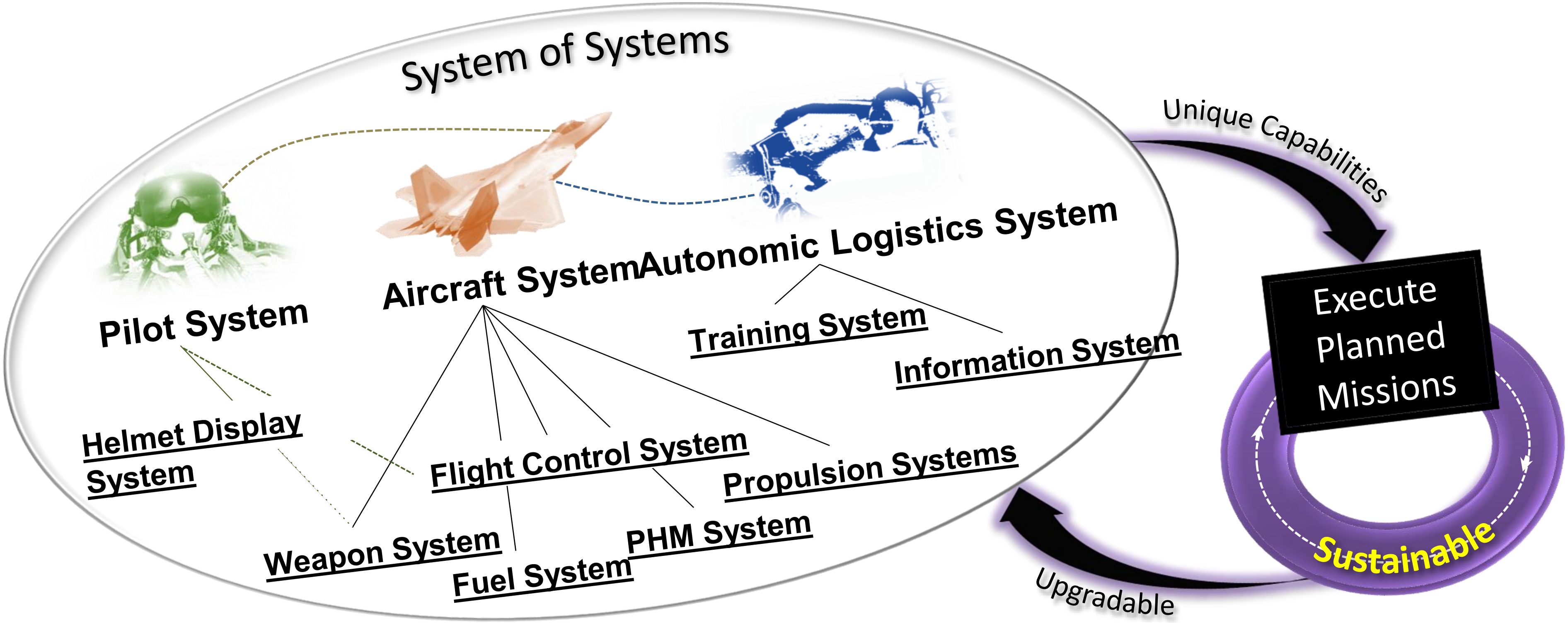
Affordability ≅
Total
Ownership
Cost(t)

where,
t=acquire ➔ operate ➔ retire

- ✓ **Affordability is assessed based on cost projection over a desired time line.**
- ✓ **Affordability Performance is influenced by the accuracy of such projection and the organizations' ability to execute a defense contract.**

The Challenges

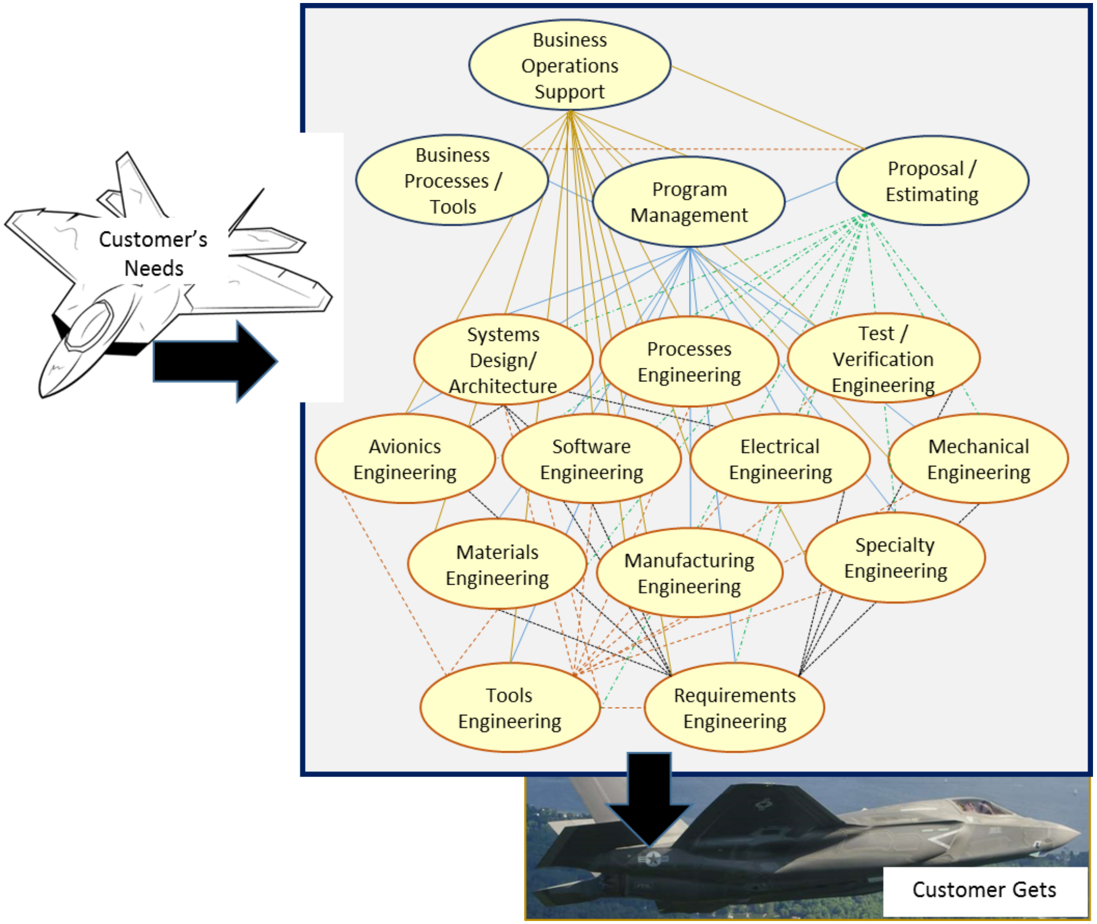
- System of Systems (SoS) is a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. (DoD Defense Acquisition Guidebook (DAG) [2008])
- Example:



The Challenges . . .

SoS Engineering Activities not Integrated with Others

- SoS systems engineering deals with planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into an SoS capability greater than the sum of the capabilities of the constituent parts [DoD, 2004(1)].



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The Challenges . . .

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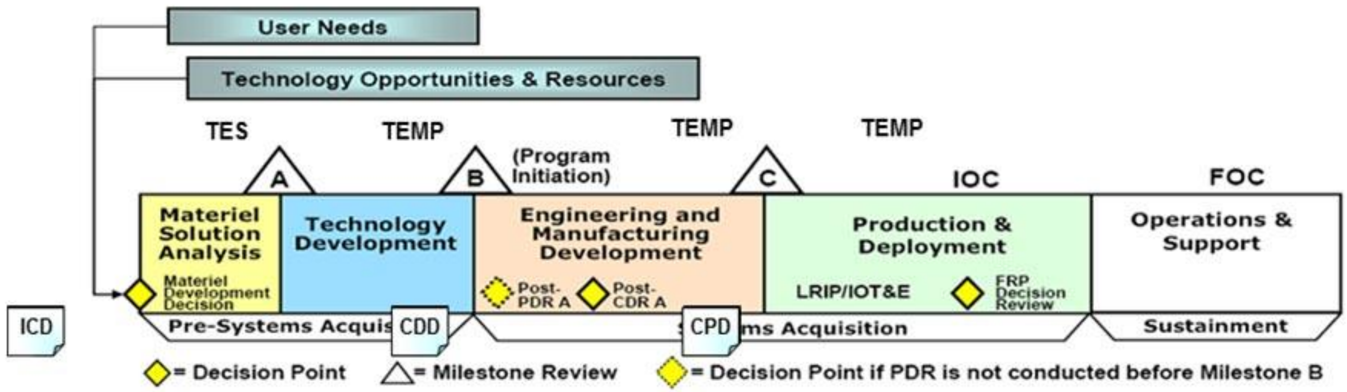
System of Systems' Acquisition Cycle is too Long

Primary Goal is to incentivize greater and timely innovation. (Better Buying Power 3.0)

➢ United States Defense Systems Life Cycle



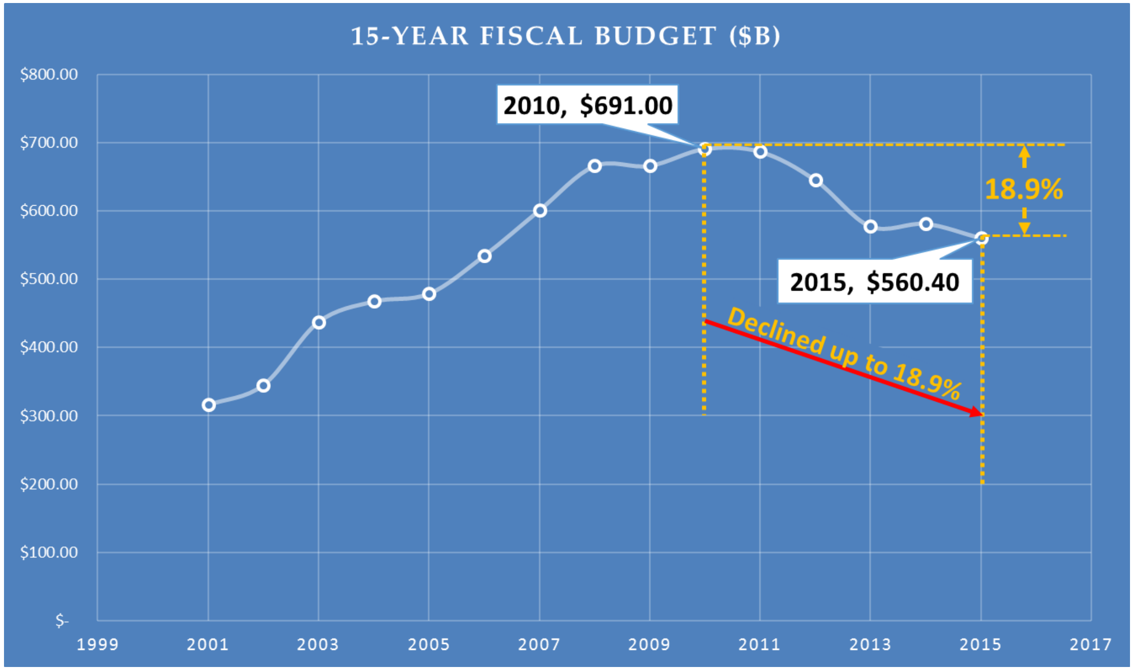
•Technology Development Strategy (TDS) •Test Evaluation Strategy (TES) •ID emerging T&E capability requirements •ID T&E resources •Develop T&E requirements in RFP •Annual Report	•Test and Evaluation Master Plan (TEMP) •Execute T&E Program •Provide T&E results for OIPT/DAB •CDD requirements for testability and evaluation •TRL Evaluation •T&E requirements in RFP •Annual Report	•Test and Evaluation Master Plan (TEMP) •Execute T&E Program •Provide T&E results for OIPT/DAB •Support SE Tech Review (PDR) •CPD requirements for testability and evaluation •Define system capabilities and limitations •Discovery and deficiencies •Annual Report	•Test and Evaluation Master Plan •Verification of corrections for deficiencies •T&E results for OIPT/DAB •OTRR •IOT&E •Annual Report	•Follow-on DT and OT •Verification of corrections for deficiencies •Develop T&E programs to support upgrades, modifications, increments

ICD: Initial Capabilities Document | CDD: Capabilities Development Document | CPD: Capabilities Production Document

The Challenges . . .

US DoD Acquisition Budget Continues to Decrease While Threats Increase

Since the United States implemented the Budget Control Act (BCA) in 2011 and followed by the budget sequestration in 2013, the DoD budget **has been reduced about 16% (rounded)** from its all-time high in 2010 [51], i.e. the DoD budget in 2015 was $560.40 billion compared to $691.00 billion in 2010, which is $130.6 billion less



At the same time, threats to the U. S. have been increased since 2010

How Do Industries Address These Challenges?

Current Literature and Industrial Practices

There are numerous processes, tools, best practices, and methodologies created by Systems Engineering community which attempted to *improve* cost and schedule performance. However, an *integrated* and *controlled* methodology for measuring the organizations' ability to meet cost, schedule, and technical target is still missing. [Dong & Stracener 2016]

Therefore,

there is a critical need for a methodology that enables weapon developers to predicting development program performance in achieving technical requirements within cost and schedule targets

Part I:

The Introduction of the AMAM

Affordability Maturity Assessment Methodology

➢ Description

The AMAM constitutes a new systems engineering capability for assessing and measuring **organizations' ability** to develop and build defense systems within cost and schedule targets

➢ Objective:

Do more with less by minimizing cost and schedule incursion and optimizing efficiency through focused systems engineering and program management best practices

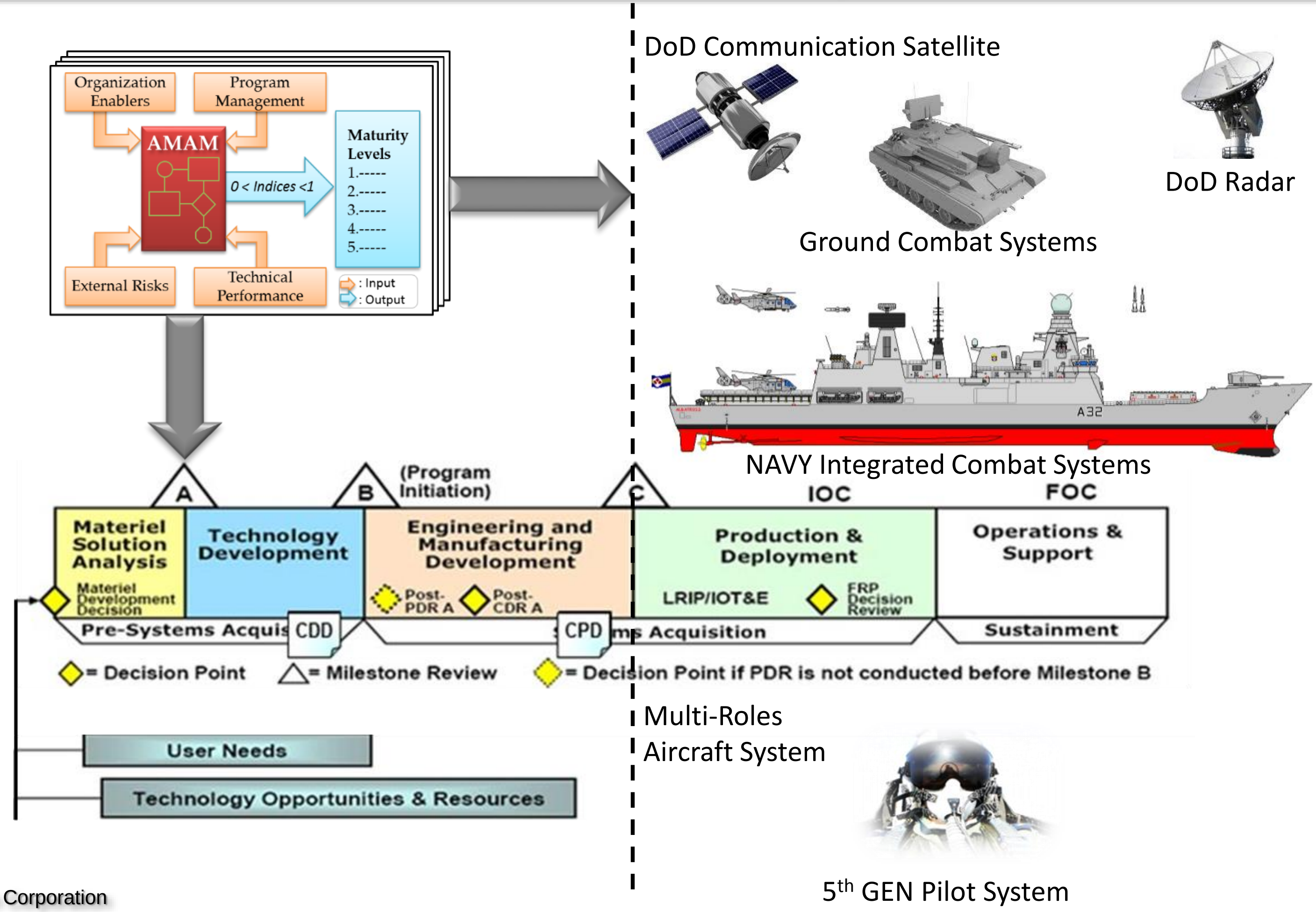
➢ Limitations / Constraints

- Pairing the right Skills with the right jobs
- The ability to win a war is our nation's greatest priority
- Inaccurate Estimation

Affordability Maturity Assessment Methodology

➢ Application

The AMAM is intended to be applied to any U. S. DoD materiel acquisition program from Milestone A through Milestone C to assess the developer's ability to develop a new technology or complex system within cost and schedule targets.



Affordability Maturity Assessment Methodology

- **Cost & Schedule Performance Index (CoSh)**

$$A_{CT} = \prod_{i=1}^{n} \frac{1}{C_i T_i} \begin{Bmatrix} C_i > 0 \\ T_i > 0 \end{Bmatrix}$$

C_i: Capability Cost Index = $\frac{C_{i\_actual}}{C_{i\_baseline}}$

T_i: Capability Schedule Index = $\frac{T_{i\_actual}}{T_{i\_baseline}}$

A_{CT}: Program Mgmt. Maturity Index

- **Technical Performance Risk Index (TecPri)**

$$A_R = 1 - TRI_{ALL} \ (TRI_{ALL} \leq 1)$$

TRI_{ALL}: Technical Performance Risk Index
A_R: Affordability Risk Index

- **Engineering & Program Management (PM) Capability (OrgCap)**

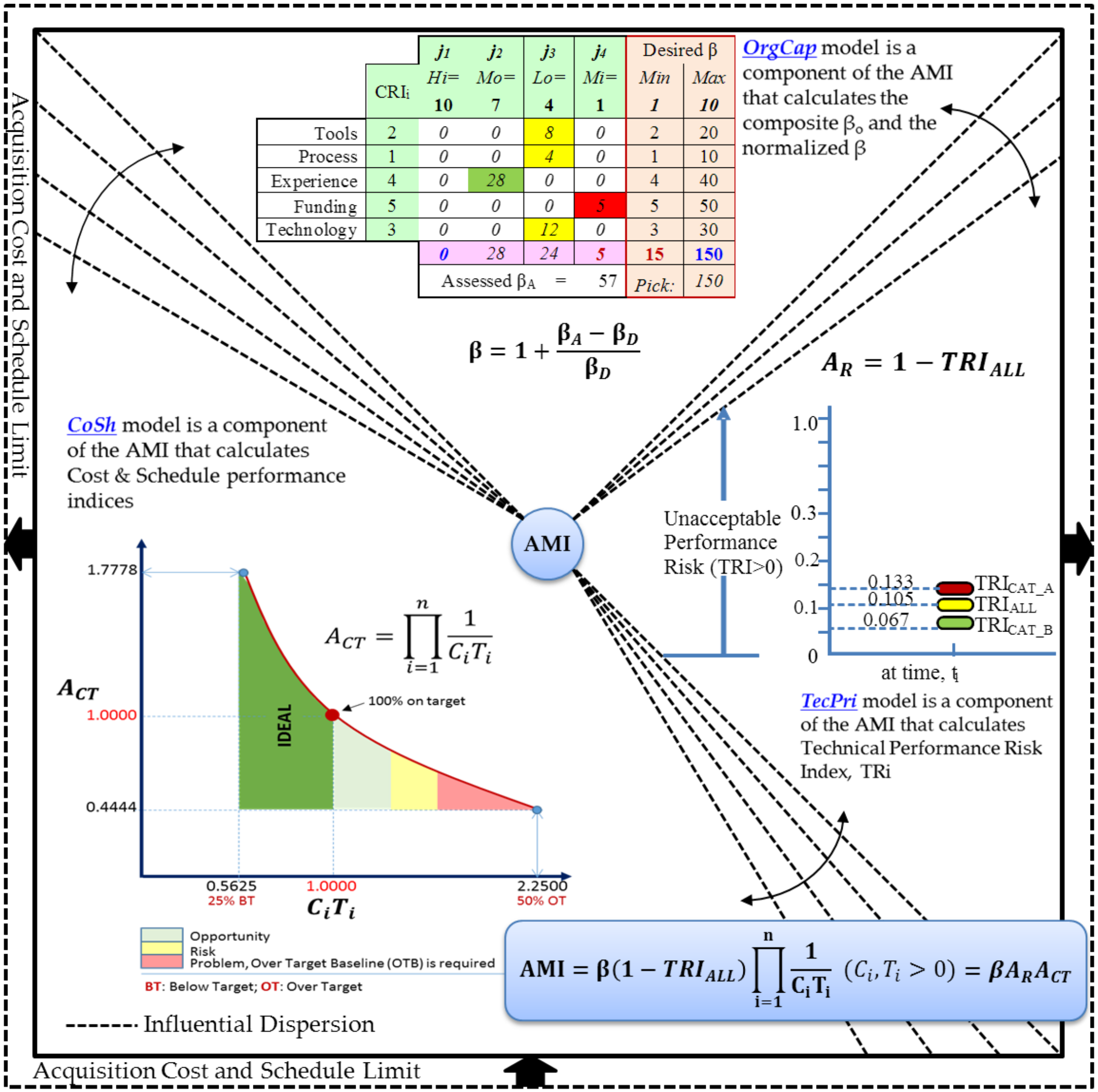
$$\beta_D = \sum_{i=1,j=1}^{\mathrm{n},k} CRI_i . M_j = \max$$

$$\beta_A = \sum_{i=1,j=1}^{\mathrm{n},k} CRI_i . M_j = actual\ score$$

$$\Rightarrow \beta = \max\left\{1 + \frac{\beta_A - \beta_D}{\beta_D}, 1\right\}$$

β_D: Program/organization desired composite score
β_A: Program/organization access (actual) composite score
β: Normalized Engrng. & PM Maturity Index

Affordability Maturity Assessment Methodology

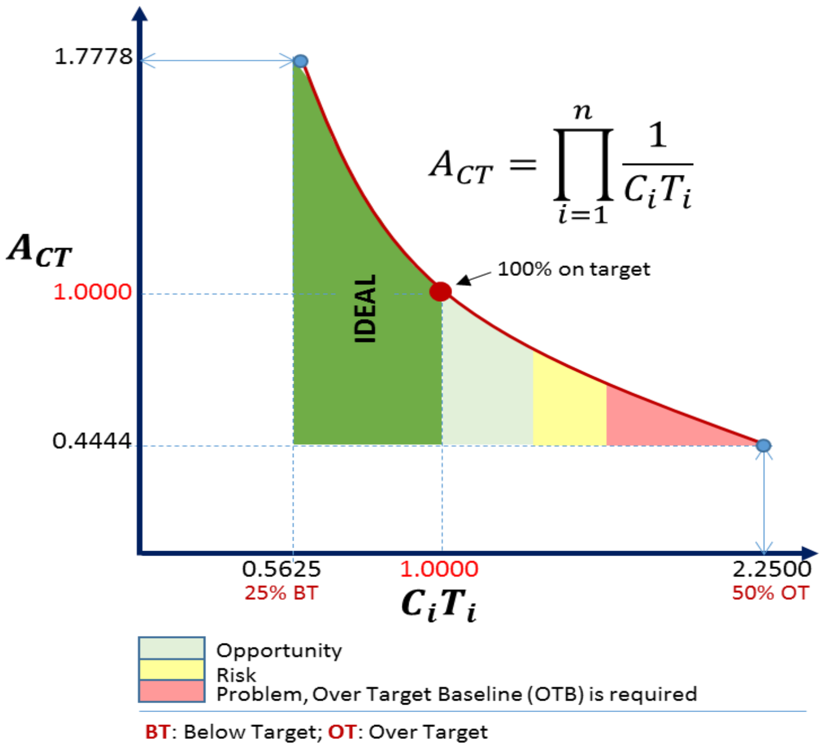


	CRI_i	j_1 Hi= 10	j_2 Mo= 7	j_3 Lo= 4	j_4 Mi= 1	Desired β Min 1	Desired β Max 10
Tools	2	0	0	8	0	2	20
Process	1	0	0	4	0	1	10
Experience	4	0	28	0	0	4	40
Funding	5	0	0	0	5	5	50
Technology	3	0	0	12	0	3	30
		0	28	24	5	15	150
		Assessed β_A	=		57	Pick:	150

Affordability Maturity Assessment Methodology

➢ Cost & Schedule Performance Index for PM

Affordability Performance Index for Program Manager



Define: "n" as number of capabilities being assessed; C_i is the Cost performance index of an i^{th} capability (where $i = 1 \ldots n$); C_{actual^i} is the actual $ spent on developing i^{th} capability and $C_{baseline^i}$ is budgeted $ for the same capability; then

$$C_i = \frac{C_{actual^i}}{C_{baseline^i}} = \begin{cases} < 1, underrun \\ = 1, on\ target \\ > 1, overrun \end{cases}$$

Define: "n" as number of capabilities being assessed; T_i is Schedule performance index of an i^{th} capability (where $i = 1 \ldots n$); T_{actual^i} is the *time* spent on developing i^{th} capability and $T_{baseline^i}$ is allowed *time* for developing the i^{th} capability; then

$$T_i = \frac{T_{actual^i}}{T_{baseline^i}} = \begin{cases} < 1, ahead \\ = 1, on\ track \\ > 1, behind \end{cases}$$

Define: A_{CT} as *affordability risk index* of based upon *cost* and *schedule* performance indices, then A_{CT} is calculated as follow:

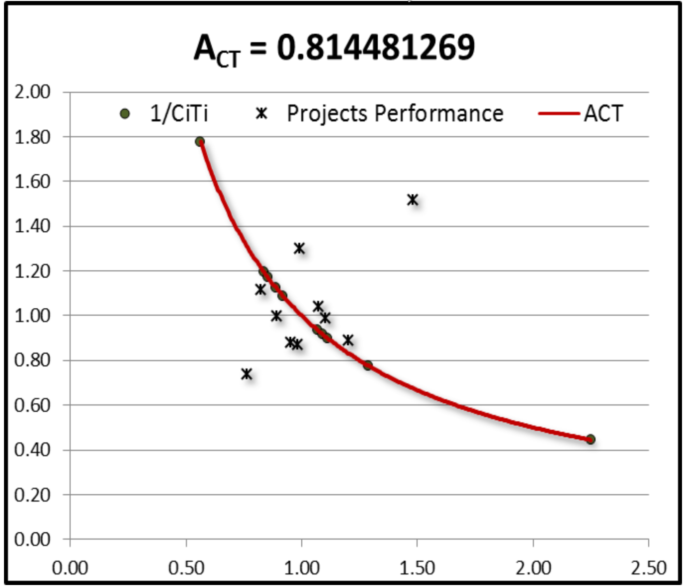
$$A_{CT} = \prod_{i=1}^{n} \frac{1}{C_i T_i}, \text{for } C_i > 0 \text{ and } T_i > 0$$

Affordability Maturity Assessment Methodology

➢ Cost & Schedule Performance Index - Example

Example of *cost* and *schedule* performance of a random ten projects. The results show that five projects are considerably desirable and other fives are struggling

	A_{CT} =		0.814481269	
Project	C_i	T_i	C_iT_i	$1/C_iT_i$
1	0.99	1.30	1.2870	0.7770
2	0.76	0.74	0.5624	1.7781
3	1.20	0.89	1.0680	0.9363
4	1.10	0.99	1.0890	0.9183
5	1.07	1.04	1.1128	0.8986
6	0.89	1.00	0.8900	1.1236
7	1.48	1.52	2.2496	0.4445
8	0.82	1.12	0.9184	1.0889
9	0.95	0.88	0.8360	1.1962
10	0.98	0.87	0.8526	1.1729



Ground Rules & Assumptions:

An organization's ability to design and performance work packages within each major Work Breakdown Schedule (WBS) and the decomposed WBSs is assessed and predicted in β. The mathematical model defined herein is for assessing a recent performance risk index and the result to be integrated with β to predict future performance of the remaining works cope.

Affordability Maturity Assessment Methodology

➢ Technical Performance Risk Index

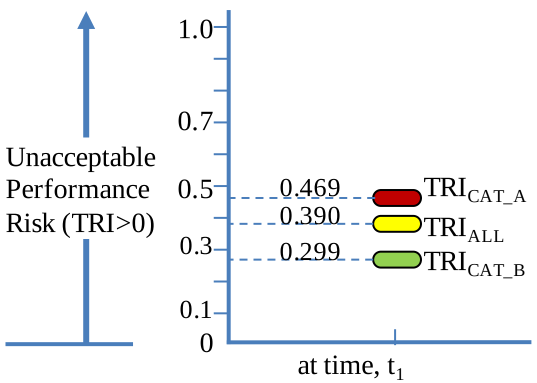
Illustration of TPM Risk Index and Affordability Risk Index Calculations

$$TRI_{CAT\_A} = 1 - [(\sum_{i=1}^{n} Wt_i \frac{1}{NA_i})/\sum_{i=1}^{n} Wt_i]$$

Category A:	T	A	NAV	1/NA	Wt
Payload (lbs)	25000	35000	1.400	0.714	1
Sortie (mins)	50	100	2.000	0.500	2
MTBR (mins)	120	240	2.000	0.500	1
Sig.Range(nm)	8	16	2.000	0.500	3
Calculated TRI: 0.469					

$$TRI_{CAT\_B} = 1 - [(\sum_{i=1}^{n} Wt_i NAV_i)/\sum_{i=1}^{n} Wt_i]$$

Category B:	T	A	NAV	Wt
Speed (nmph)	400	320	0.800	1
Range (nm)	950	680	0.716	2
Altitude (ft)	45000	38000	0.844	1
MTBF (Hrs)	1800	950	0.528	1
Calculated TRI: 0.279				



$$TRI_{ALL} = [Wt *_{CAT_A}.TRI_{CAT_A} + Wt *_{CAT_B}.TRI_{CAT_B}]/(Wt *_{CAT_A} + Wt *_{CAT_B})$$

Summary	TRI	Wt*	Overall TRI
CAT A TPMs	0.469	7	**0.390**
CAT B TPMs	0.279	5	

$$\boxed{(A_R = 1 - TRI_{ALL} = 0.610)}$$

Ground Rules & Assumptions:

An organization's ability to performance all required technical performance measures (TPMs) and mange technical risks is assessed and predicted in β. The mathematical model defined herein is for assessing a recent Technical Performance Measures Risk Index (TRI) and the result to be integrated with β to predict future performance of the remaining works cope.

Affordability Maturity Assessment Methodology

Engineering & Program Management Capability - Example

Let β_A be the organization capability (or maturity) assessed score, β_D be the organization desired maturity score, then the normalized maturity index, ***β,*** is calculated as follows:

Simulated Composite Value of β_A

	$M_{j=1...k}$	j_1	j_2	j_3	j_4	Desired β	
	$CRI_{i=1...n}$	Hi=	Mo=	Lo=	Mi=	Min	Max
		10	**7**	**4**	**1**	**1**	**10**
Tools	**2**	0	14	0	0	2	20
Process	**1**	10	0	0	0	1	10
Experience	**4**	0	28	0	0	4	40
Funding	**5**	50	0	0	0	5	50
Technology	**3**	30	0	0	0	3	30
		90	42	0	**0**	**15**	**150**
		Assessed β_A		=	132	Pick:	150

$$\boldsymbol{\beta_A = \sum_{i=1,j=1}^{n,k} (CRI_i \times M_j)}$$

$$\boldsymbol{\rightarrow \beta_A = (2).(7) + (1).(10) + (4).(7) + (5).(10) + (3).(10) = 132}$$

$$\boldsymbol{\beta_D = (M_{j=k}) \times \sum_{i=1}^{n} CRI_i}$$

$$\boldsymbol{\rightarrow \beta_D = (10)x(2 + 1 + 4 + 5 + 3) = 150}$$

$$\boldsymbol{\beta = max\left\{1 + \frac{\beta_A - \beta_D}{\beta_D}, 1\right\}}$$

$$\boxed{\boldsymbol{\rightarrow \beta = \left\{1 + \frac{132 - 150}{150}\right\} = 0.880}}$$

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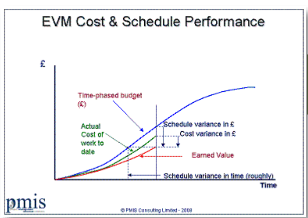
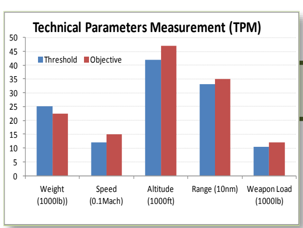
The AMI Mathematical Model:

i/j	A	B	C	D
1	*Process Capability*			
4	*SE Re-Use*			
7	*Program Mgmt*			
	SE Tools			
10	*Past Success*			
12	*Funding Power*			
15	*Complexity . . .*			

$$\boldsymbol{\beta = max\left\{1 + \frac{\beta_A - \beta_D}{\beta_D}, 1\right\}}$$



$$\boldsymbol{A_{CT} = \prod_{i=1}^{n} \frac{1}{C_i T_i} \begin{Bmatrix} C_i > 0 \\ T_i > 0 \end{Bmatrix}}$$



$$\boldsymbol{A_R = 1 - TRI_{ALL}\ (A_R \le 1)}$$

Integrated Mathematical equation to Calculate AMI

$$\boldsymbol{\beta}.\,(1 - \boldsymbol{TRI_{ALL}}) \prod_{i=1}^{n} \frac{1}{\mathbf{C_i T_i}} \begin{Bmatrix} \mathbf{C_i} > 0 \\ \mathbf{T_i} > 0 \\ 0 < \mathbf{TRI_{ALL}} < 1 \end{Bmatrix}$$

Affordability Maturity Assessment Methodology

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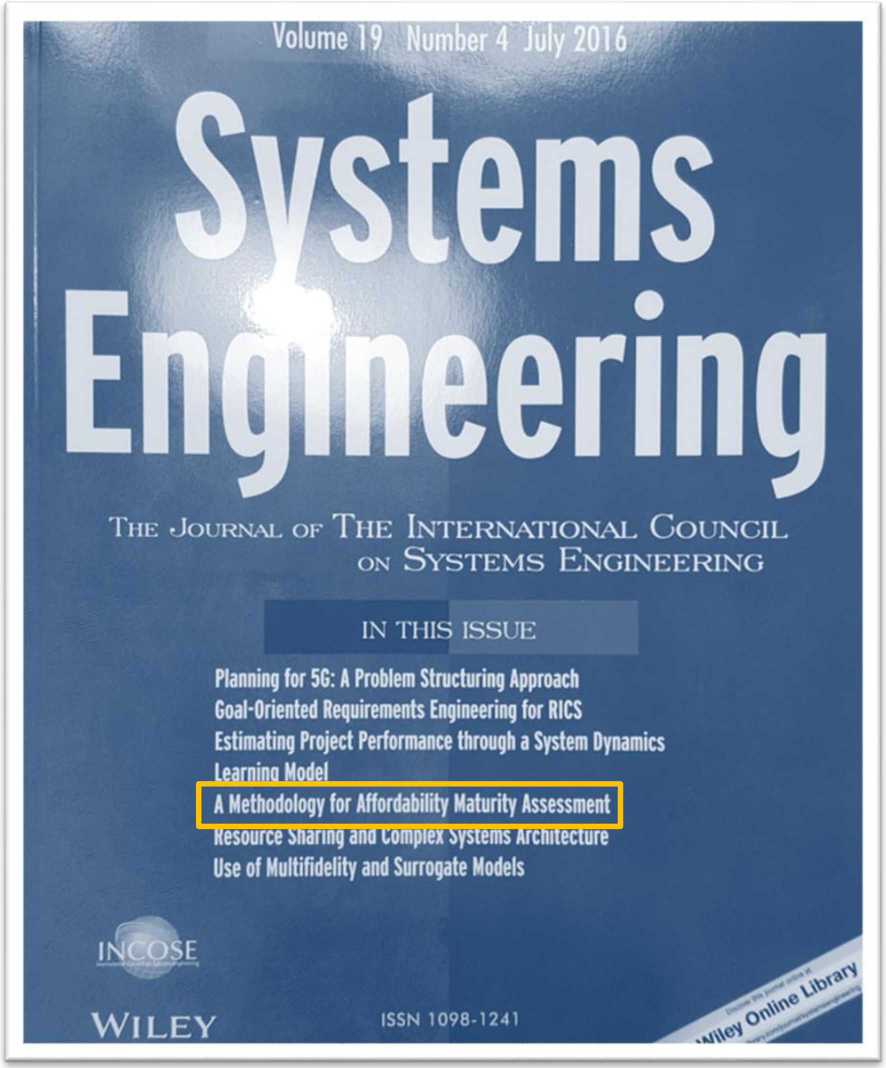
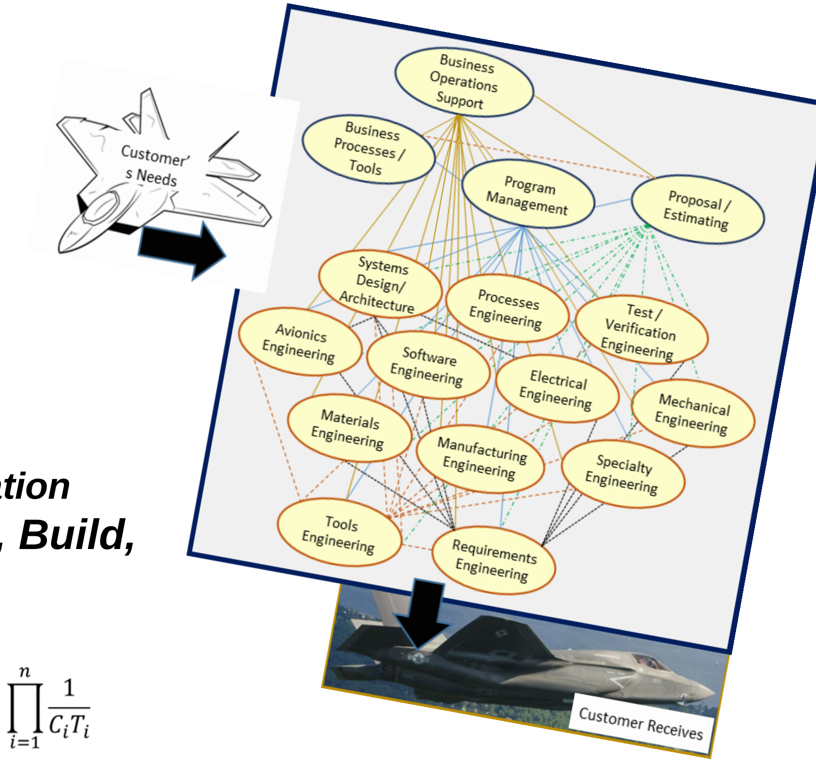


What Does It Take To Be Affordable?

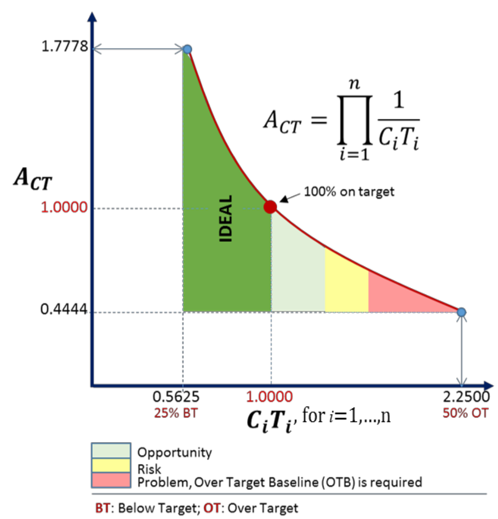


- **Accurate Estimation: Contract Proposals**
  - ***Requirements***
  - ***Complexity***
  - ***Risks***
  - ***Assumptions***

- **Perform:**
  - ***Design, Implementation, Test/Ver./Val.:***
    - ***Concurrency Design Changes Implementation***
  - ***Procurement, Mfg. Processes, Mfg. Tools, Build, Tests, and Delivery***
  - ***Quality***

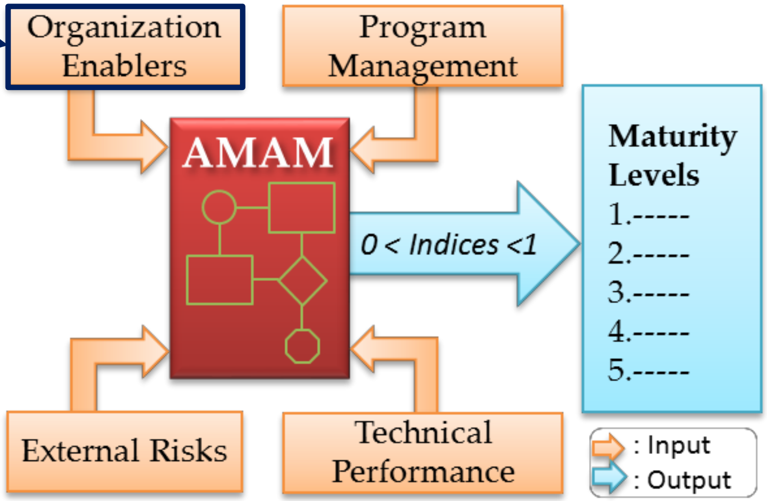
- **Manage the Unknowns:**
  - ***Cost = c(r)***
  - ***Schedule = t(r)***

- **Manage the Enablers**



Enablers . . .

- Engineering Processes, Tools, and Skills
- Program Management Processes, Tools, and Skills
- Production Processes, Tools, and Skills
- Procurement Processes, Tools, and Skills
- Sustainment Processes, Tools, and Skills



Summary

- **Affordability Means differently to Customer and Developer:**
  - ***Continue Performing Affordability Assessment***
  - ***Constitute Affordability as a Systems Engineering Role***
- **Complexity is Affordability Challenge:**
  - ***Devil is in the details***
  - ***Understand total effort***
- **What Does It Take to Meet Cost and Schedule?**
  - ***Accurate Estimation, Perform, and Manage the Unknowns & Enablers***

Part II:

How to Apply the AMAM

Next Chapter Meeting

Lockheed Martin Corporation

AERONAUTICS
- Tactical fighters
- Tactical and strategic airlift
- Advanced Development

ROTARY & MISSION SYSTEMS
- Radar and surveillance systems
- Training and logistics solutions
- Simulation technologies
- Sikorsky

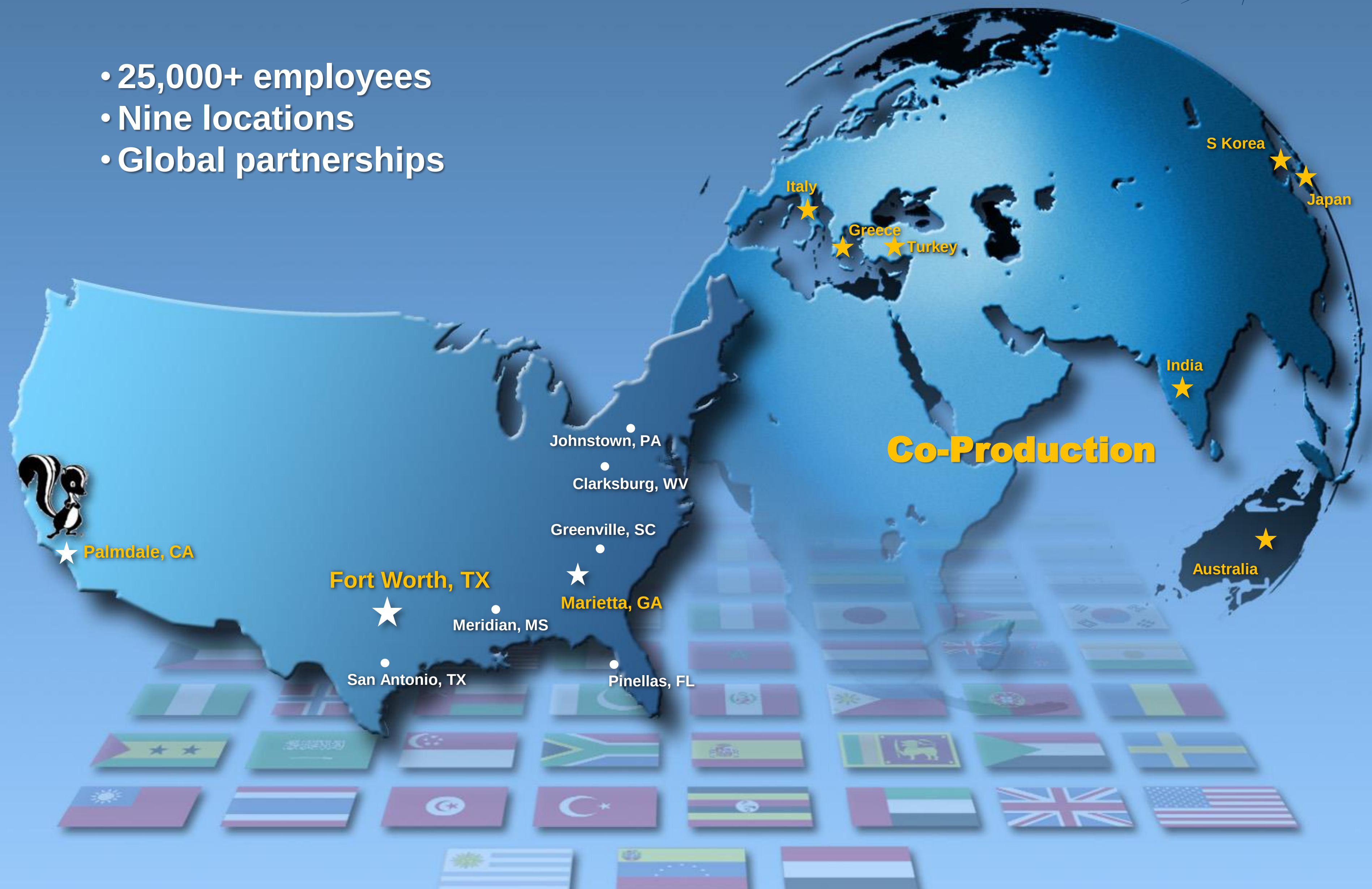
SPACE SYSTEMS
- Surveillance & navigation
- Global communications
- Human space flight
- Strategic and defensive systems

MISSILES & FIRE CONTROL
- Air and missile defense
- Fire control and situational awareness
- Nuclear systems and solutions

LOCKHEED MARTIN INTERNATIONAL

Lockheed Martin Aeronautics

- 25,000+ employees
- Nine locations
- Global partnerships



Aeronautics Portfolio

Questions?