Manufacturing Readiness Levels (MRLs)
Manufacturing Readiness Assessments (MRAs)
In an S&T Environment

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Why MRLs?

"Advanced weapon systems cost too much, take too long to field, and are too expensive to sustain" -- Congress, OSD, CSAF, GAO

- Production/manufacturing processes are major contributor
  - A GAO study of core set of 26 programs: RDT&E costs up by 42% and schedule slipped by 20%
    - $42.7B total cost growth
    - 2.5 years average schedule slip
  - Characteristics of successful programs:
    - *Mature technologies, stable designs,* ***production processes in control***
    - ***S&T organization responsible for maturing technologies****, rather than program or product development manager*
- Need way to mitigate impact of diminishing manufacturing infrastructure
  - People, policy, programs gutted
  - Lost recipe on how to manage manufacturing risk
  - Won't get infrastructure back but still need to manage manufacturing risk

Technology Readiness Levels (TRLs)

Provide a common language and widely-understood standard for:

- Assessing the *performance maturity* of a technology and plans for its future maturation
- Understanding the level of performance risk in trying to transition the technology into a weapon system application

TRLs leave major transition questions unanswered:

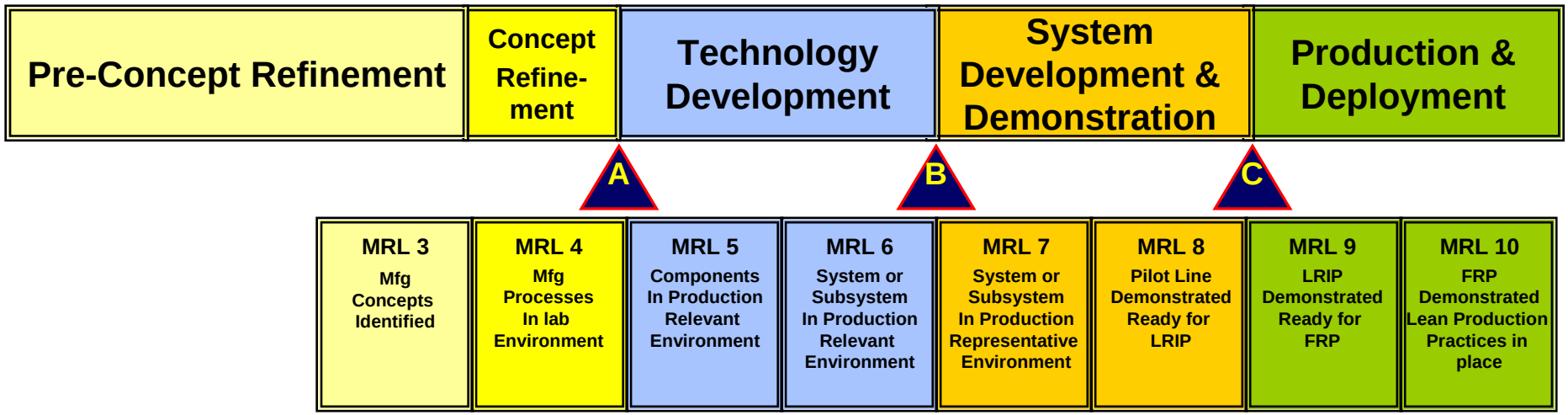
- Is the technology producible? Reproducible?
- What will these cost in production?
- Can these be made in a production environment?
- Are key materials and components available?

Manufacturing Readiness Levels
(MRLs)

- Common language and standard for
  - Assessing the ***manufacturing maturity*** of a technology or product and plans for its future maturation
  - Understanding the level of manufacturing risk in trying to produce a weapon system or transition the technology into a weapon system application
- Designed to complement TRLs
- Designed to help set the agenda for manufacturing risk mitigation
- Usage
  - Army, for Future Combat Systems development efforts
  - Missile Defense Agency using EMRLs on all development programs
  - Several defense primes using on weapon system programs
  - ***Mandated by AFRL on all hardware CAT I ATDs***

MRL Relationships

Relationship to System Acquisition Milestones



Relationship to Technology Readiness Levels

MRL Evaluation Criteria (Threads)

- Technology and Industrial Base
- Design
- Materials
- Cost and Funding
- Process Capability and Control
- Quality Management
- Manufacturing Personnel
- Facilities
- Manufacturing Management

MRL Evaluation Criteria (Threads)

S&T Phase		6.2 / 6.3	6.3 / 6.4	6.3 / 6.4 / 7.8	6.4 / 6.8 / 7.8	7.8
Acq Phase		Pre CR		TD		SDD
Thread	Sub-Thread	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7
Technology & Industrial Base	**Technology Maturity**	TRL 3	Should be assessed at TRL 4.	Should be assessed at TRL 5.	Should be assessed at TRL 6.	Should be assessed at TRL 7
	Technology Transition to Production	Potential manufacturing sources identified for technology needs. (Commercial/Government, Domestic/Foreign)	Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes.	Industrial Base assessed to identify potential manufacturing sources.	Industrial Capability Assessment (ICA) for MS B has been completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified.	Industrial capability to support production has been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary.
	Manufacturing Technology Development	Initial demonstration of Mfg Science	Mfg Science & Advanced Mfg Technology requirements identified	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.
Design	**Producibility Program**	Evaluate relevant materials/processes for manufacturability & producibility	Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. Manufacturing Processes assessed for capability to test and verify in production, and influence on O&S.	Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineering Plan (SEP) requires validation of design choices against manufacturing process and industrial base capability constraints.	Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. DFMA) initiated.
	Design Maturity	Evaluate product lifecyle requirements and product performance requirements.	Systems Engineering Plans and the Test and Evaluation Strategy recognize the need for the establishment/validation of manufacturing capability and management of manufacturing risk for the product lifecycle. Initial Key Performance Parameters (KPPs) identified.	Identification of enabling/critical technologies and components is complete and includes the product lifecycle. Evaluation of design Key Characteristics (KC) initiated.	Basic system design requirements defined. All enabling/critical technologies/components have been tested and validated. Product data required for prototype manufacturing released. A preliminary performance as well as focused logistics specification is in place. Key Characteristics and tolerances have been established.	Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant.

Air Force MRL Implementation Approach

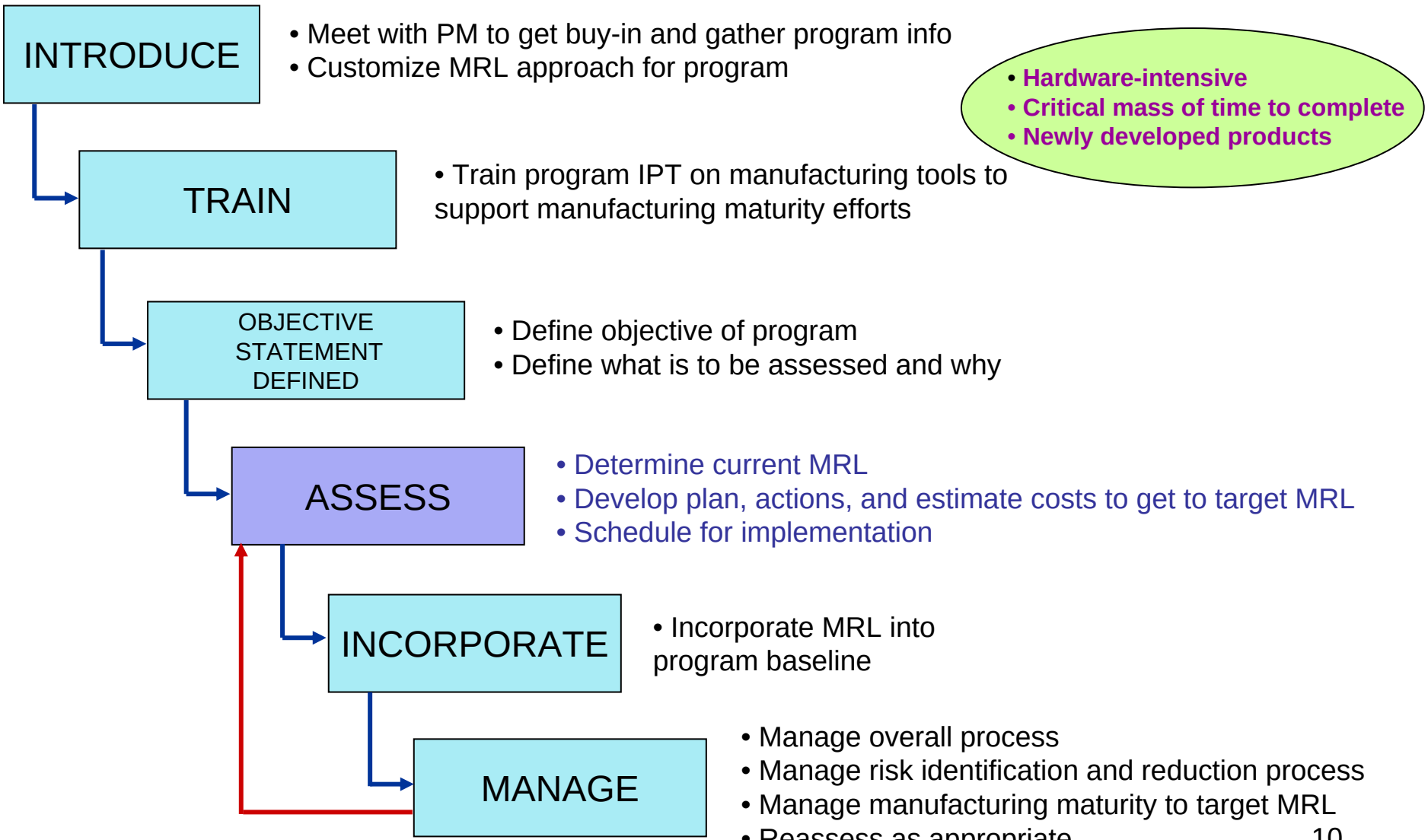
In partnership with Joint Defense Manufacturing Technology Panel (JDMTP)

- Conduct pilot MRAs on various programs
  - Advanced Technology Demonstration programs
  - Weapon system acquisition programs
  - Demonstrate benefits of using MRLs
- Conduct training for key program personnel
  - What are MRLs, how to conduct an MRA
    - Air Force ManTech personnel
    - Category I ATD IPTs and ACAT pilot program personnel
  - Utilize various training materials that can be tailored
  - Transition to DAU once MRLs are in policy
- Put MRLs into policy documents
  - AFRL, AFMC, AF, DoD

MRL Incorporation into AFRL ATDs

- AFRL/RXM conducted ATD pilot assessments on five ATDs, Nov 04 – May 05
  - Identified gaps in manufacturing maturity that would delay technology transition upon ATD graduation
    - Highlighted what was required to turn technologies into products
  - Tasked by AFRL/CA to implement MRLs into all “hardware” intensive ATDs
    - Developed three year plan to reach steady state
    - Developed basic MRL implementation process
    - Developed training for ATD IPTs and ManTech personnel
- Identified core ManTech funding for MRAs and selected follow-on MRL maturation
- Now taking on all CAT I “hardware” intensive ATDs

Manufacturing Readiness Level Implementation
Approach (ATDs)



MRA Deliverables

- Identification of ***current MRL***
- Identification of key factors where manufacturing readiness falls short of ***target MRL***
  - Define driving issues
  - Define high risk areas
- Identify programs and plans to reach target MRL
  - Generate the manufacturing maturation plan (MMP)
- Assess type and significance of risk to cost, schedule and/or performance

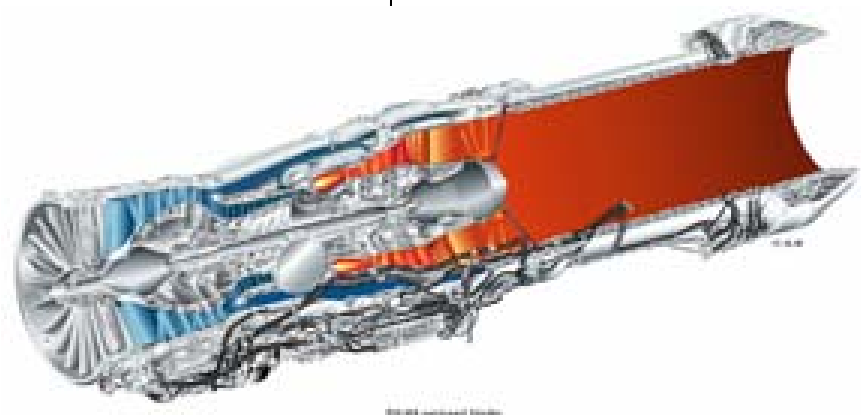
Emerging MRA Successes

High Durability Hot Exhaust Structures

- **Provided identification of high risk processes and single point failures driving scale-up from MRL 3**
- **Maturation plan provides awareness of issues relating to move to new production facility**
- **Follow-on MRA at new facility will help ensure transition success**

F135

- **Enabling opportunity to accelerate transition for F135 thrust improvement by ~4 years**
- **Advanced feature high cost driver: must overcome producibility issues**
- **Developed plan to mature from MRL 3 to 5 leveraging commercial and military IR&D, F135 program, and ManTech funding**



Emerging MRA Success

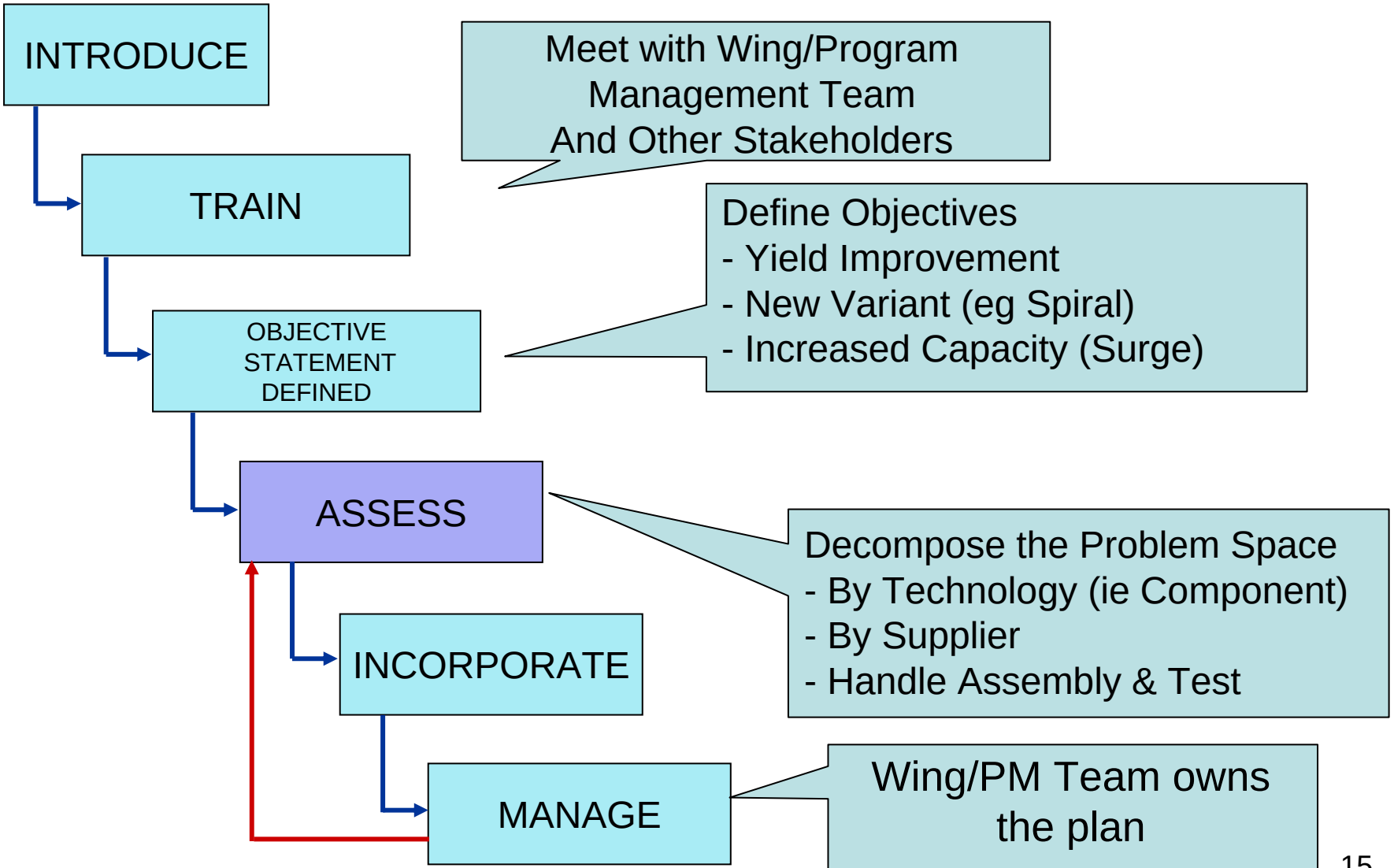
Sensor Hardening for Tactical Systems (Two contractors)

- Identified common manufacturing readiness driver among both contractors -- Optical Power Limiter (OPL) -- MRL 3
- Drilling down into OPL supplier processes to identify root issues -- OPL also likely driver on Sensor Hardening for UAS ATD
- MRA enabling identification of common manufacturing issues and ManTech investment opportunity

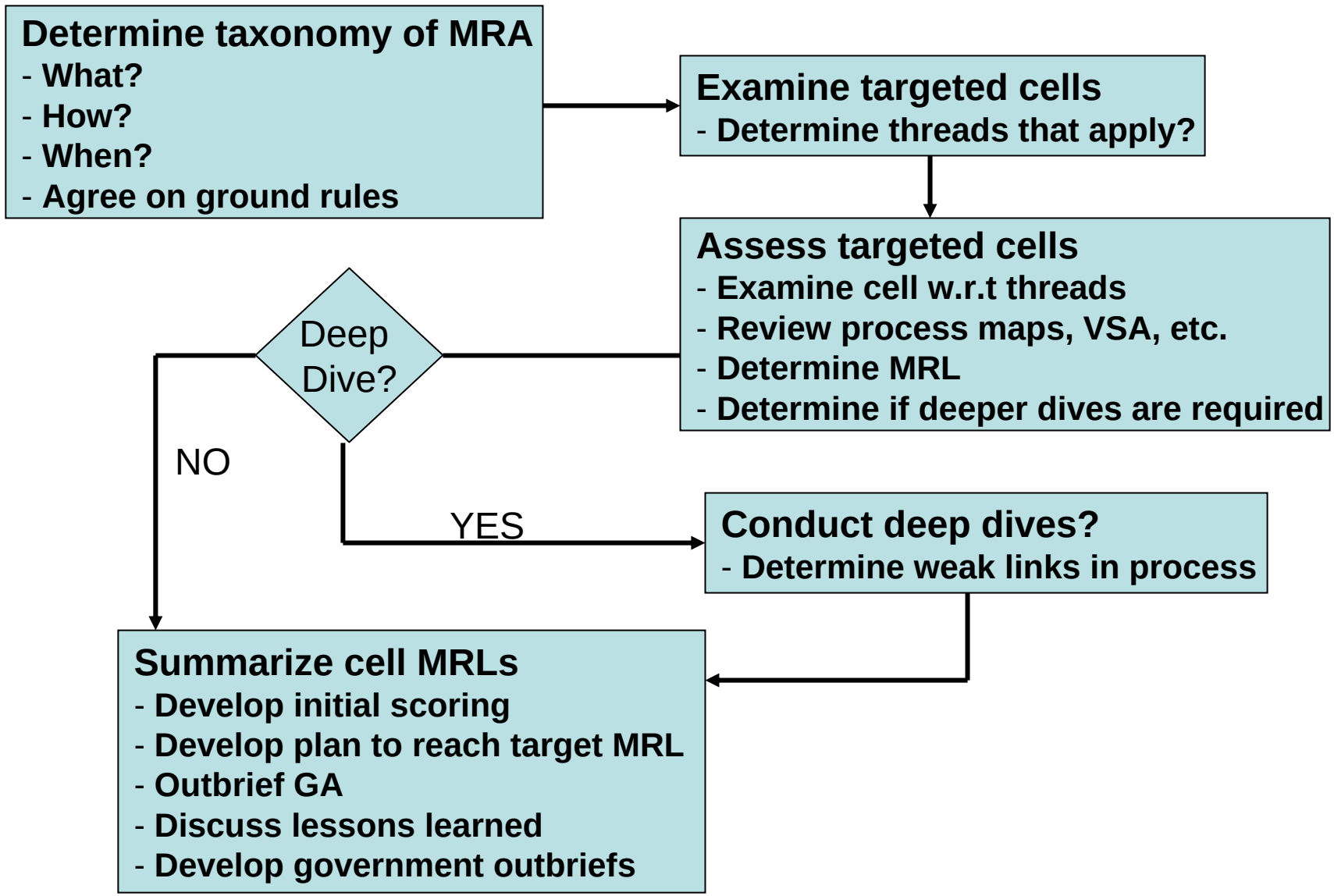
ACAT MRA Pilot

- **Translate the successful MRL ATD process to acquisition programs**
- **Common themes**
  - **Utilize approximately the same process**
  - **Utilize current MRL definitions to assess against**
  - **3-5 people per MRA**
- **What is different**
  - **ATDs focus on MRL 3 – MRL 6**
    - **Assess manufacturing maturity with a goal of transition/implementation**
  - **ACATs focus on MRL 4 – MRL 9**
    - **Schedule, cost, manning considerations**
    - **Milestone decisions**
    - **Production planning process**
    - **Will require a more rigorous approach**
- **Develop and document a structured ACAT assessment approach**
  - **MRA Deskbook**
    - **First draft completed Mar 07 based on ATD and limited ACAT experience**
    - **Drafted with SAF/AQRE, MRL Working Group, and ASC/EN**
  - **Test drive on acquisition programs**
    - **Update based on lessons learned**

Manufacturing Readiness Implementation Approach (ACATs)



ACAT MRA Process



AMRAAM

- What: Performed a system-level MRA on the AMRAAM C-7 variant
  - Looked at all test and assembly steps, including FACO
  - Fourteen key suppliers; over thirty-five technology areas examined
- Impact: Based on independent assessment, AMRAAM Group received go-ahead to proceed to next production lot for C-7 variant; reduced testing cycle time in particular cell by 90%

Some MRA Thoughts

- MRLs are not a report card
  - ***MRL 7 might not be good***
  - ***MRL 3 might not be bad***
- MRLs are a tool to manage and mitigate manufacturing risk
  - ***A common language used to assess manufacturing maturity***
  - ***Provide insight not oversight***

Some MRA Lessons Learned

- Process is more effective if company is actively engaged in the assessment
- System integration and test operations are often ripe for maturation efforts
- Resources required to conduct an MRA will vary significantly
  - Not all programs are equal
- Subject matter expertise is needed to “do it right”
- Templates and guidelines developed
  - Not a one size fits all solution
  - Engineering skills/judgment still need to be used
  - Avoid a checklist mentality

Future Steady State

- Programs utilizing MRLs
  - Funding MRL maturation
  - Understanding of manufacturing concepts
- Use of MRLs in policy
  - Program offices staffed/trained
  - Manufacturing a key component for milestone reviews
- Training
  - DAU acts as the primary DoD training agent
  - AFIT supports detailed manufacturing training

Additional Information

- MRL definitions can be found at DAU web site:
  - https://acc.dau.mil/CommunityBrowser.aspx?id=18231
    - Look for MR definitions
    - Look for MR matrix (threads)
    - Look for MRL tutorial
    - Look for MRA Deskbook
- Google – manufacturing readiness assessments

In Closing

- Using a three-pronged approach to implementation
  - Piloting and incorporating into various programs
  - Training
  - Policy insertion
- Overall implementation is progressing
  - Air Force
  - DoD
- We are still learning and applying lessons learned

Air Force is Leading DoD-wide Implementation