Aerospace Industries Association

Rotor Manufacturing Process Sub-Committee (RoMan)

Team Charter and Goals

Includes Comments from RoMan Subcommittee Meeting

March 18, 1999

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Outline

- Overview of FAA Rotor Mfg. Process Initiative
- Field Cracking Data Review
- RoMan: Charter, Members, Deliverables
- Initiative Benefits
- Projected Impact on Industry
- Strategy and Timing
- Summary/Conclusions
- Appendices
  - Jay Pardee (FAA) letter
  - Independent vendor experience with power monitoring (Caval, Volvo)
  - OEM Experience with power monitoring (GE, other)

* Overview: FAA Initiative - Rotor Manufacturing

As a result of recent service problems and FAA review of historical field data, the FAA requested AIA (Aerospace Industries Association) to establish industry best practices for the manufacture of critical rotor components in order to increase safety

- **FAA Expected Goals/Outcomes**
  1. Reduced uncontained engine failures due to manufacturing induced defects
  2. Minimized Quality Control escapes involving rotor hardware
  3. Best available technology implemented industry-wide for *manufacturing*, *inspection* and *quality control* of rotating priority parts
     - Establish all processes which are significant/critical for rotors and establish best manufacturing practices for them including qualification standards
     - Define improved control procedures for certified significant manufacturing processes
     - Develop real-time, automated quality assurance detection systems to detect process disruptions
     - Define NDT inspection techniques capable of detecting surface anomalies
     - Develop industry-wide Quality Control escape database

Uncontained Rotating Part Field Failure

Sioux City, July 1989

Event Overview

- DC10-10 crashed on landing
- In-Flight separation of Stage 1 Fan Disk
- Failed from cracks out of material anomaly
  - Hard Alpha produced during melting
  - Life Limit: 18,000 cycles. Failure: 15,503 cycles.
  - 111 fatalities
- FAA Review Team Report (1991) recommended:
  - Changes in Ti melt practices, quality controls
  - Improved mfg. and in-service inspections
  - Lifing Practices based on damage tolerance

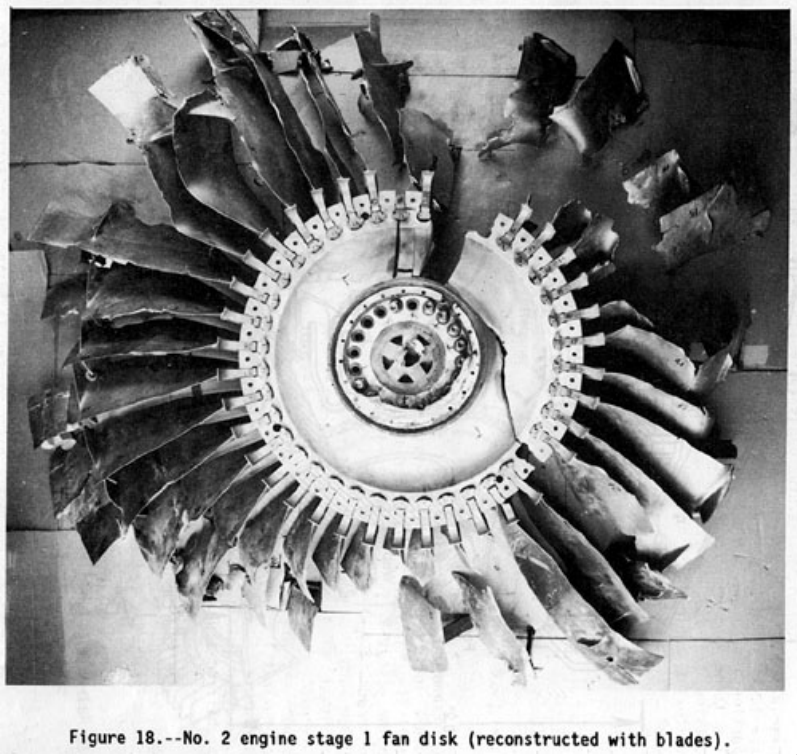


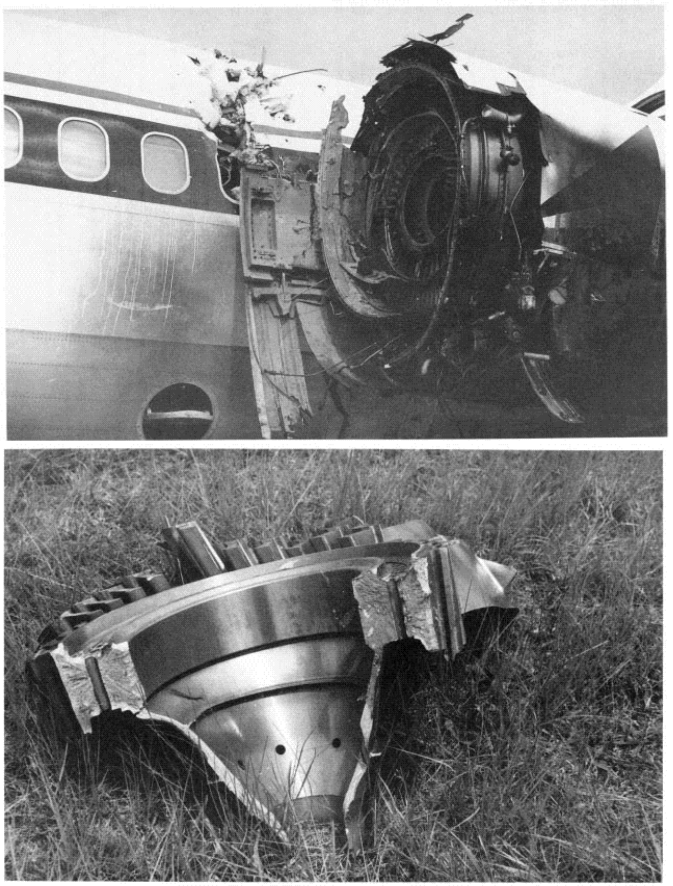
Figure 18.--No. 2 engine stage 1 fan disk (reconstructed with blades).

Sioux City event was the catalyst for unprecedented levels of industry/FAA cooperation regarding rotor safety … FAA Ti Initiative

AIA Rotor Integrity Sub-Committee (RISC) established to develop new lifing strategies

Uncontained Rotating Part Field Failure

Pensacola, July 1996



Event Overview

- MD-88 engine failure on take-off roll
- Pilot aborted take-off
- Stage 1 Fan Disk separated; impacted cabin
  - -Failure from abusively machined bolt-hole
  - -Life Limit: 20,000 cycles. Failure: 13,835 cycles.
  - -2 fatalities
- NTSB Report recommended ...
  - •Changes in inspection methods, shop practices
  - •Fracture mechanics based damage tolerance

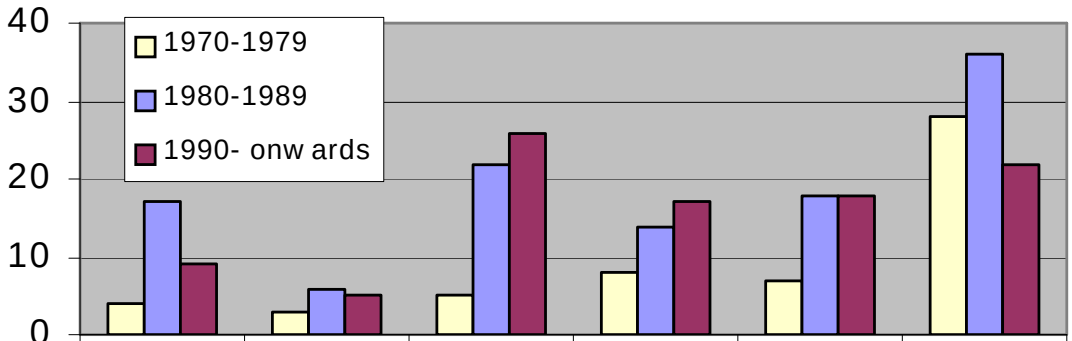
Second major premature fan disk failure in recent years due to unanticipated and undetected damage

- Spawned FAA Enhanced In-Service Inspection and Rotor Manufacturing Initiatives

* Field Cracking Data

Breakdown by Cause

Total Anomalies (All Features)



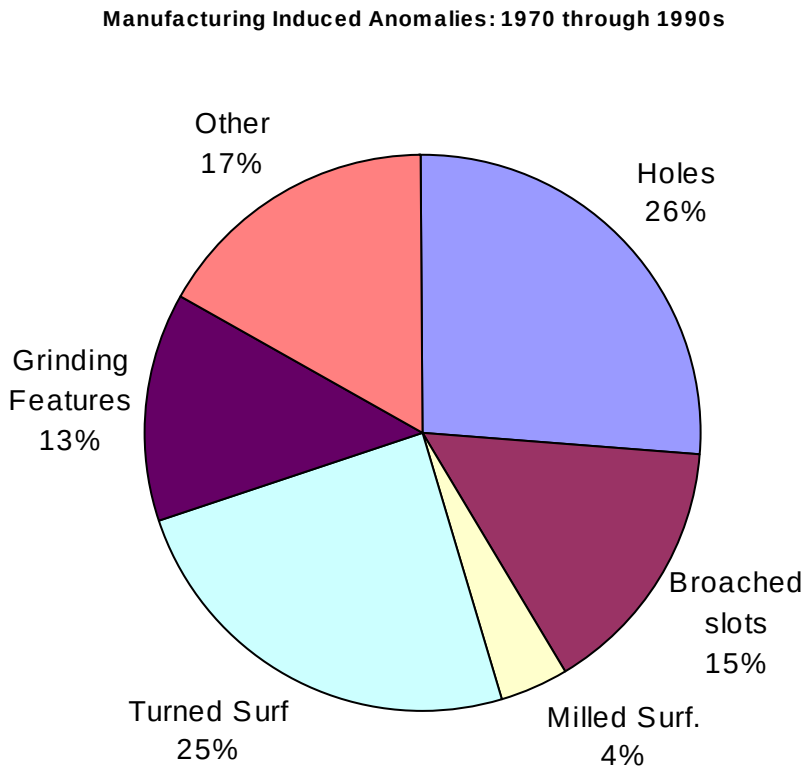
	Material	Forging	Mfg.	Maint.	Operational	Lifing Miss.
1970-1979	4	3	5	8	7	28
1980-1989	17	6	22	14	18	36
1990- onw ards	9	5	26	17	18	22

One-fourth of recent field problems attributable to manufacturing induced anomalies.

- AIA RISC Compiled Data, Given to RoMan by the FAA in Dec. 1998 Meeting.
- Data includes: cracks or events (either in field or at OEM facility) associated with critical rotors
- Dates represent when detected

* Field Cracking Data

Manufacturing Induced by Feature



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Buy-In Team Review Draft 3/15/00

Industry Data Indicates Initial Focus Should be on Hole Drilling

Industry Perspective

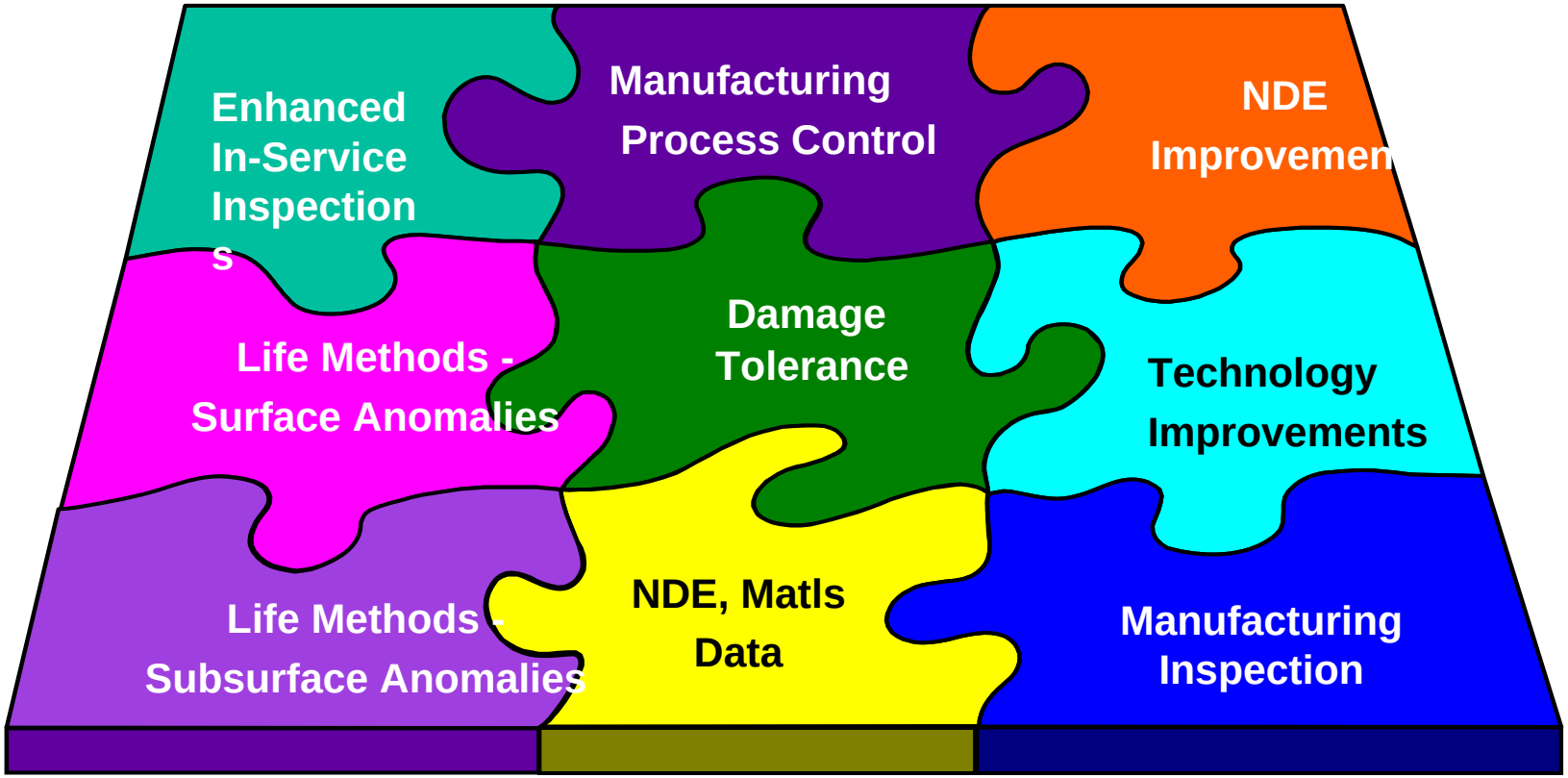
- Modern engines have excellent reliability and safety records
  - However, growing public and governmental concern over isolated, high visibility events
- Industry and FAA have been working to reduce uncontained failure rates …with some measure of success
  - Over the past 5 years, 66% drop in rate of events that hazard the aircraft
  - Rate reduction, however, being offset by growth in commercial fleet
- Recent experience … primary causal factors for uncontained failures are material, manufacturing, and maintenance/usage induced anomalies
- "Classical" failures (LCF, creep, etc) trending down; manufacturing induced anomalies showing slight upward trend
- Engine Manufacturers have recognized the need to address potential for unanticipated anomalies, and to adopt a Damage Tolerance Philosophy
- Reduction in manufacturing induced anomalies also required to complement Damage Tolerance philosophy
  - Genesis of Rotor Manufacturing Processes Initiative and RoMan

AIA/FAA Strategic Approach to Reduce Rotor Failures

- Establish design methodology to standardize damage tolerance risk assessment
- Phase reduction in target risk level to the development of enabling technology

- Reduced risk levels will result from:
  - Improved materials (**OEMs**)
  - Improved design methods (**RISC)**
  - Reduced inherent anomaly rates (**MSC)**
  - Reduced induced anomaly rates (**RoMan)**
  - Improved inspection techniques (**ETC)**

Elements of Industry Rotor Failure Risk Reduction Strategy



Reduced risk results from comprehensive strategy encompassing multiple disciplines

* Rotor Mfg.Sub-Committee (RoMan)

- Charter : *"Establish Guidelines for improved manufacturing and quality practices that work towards eliminating manufacturing Anomalies in high energy rotors"*
  - ***Focus*:** Anomalies induced after forging (that includes all manufacturing operations as well as surface finish operations).
  - **Priority:** Holes, broached slots, turned surfaces, other

- Membership:
  - Representatives from OEM's (US, Canada and Europe), Volvo
  - Technical areas: Manufacturing, Lifing, Materials/metallurgy, NDE, and QA

- FAA/ AIA Relationship:
  - RoMan subcommittee is part of AIA's Propulsion Committee (PC)
  - Work under FAA sponsorship (FAA rep is a nonvoting participating member)
  - FAA is "clearing house" to transfer safety related information

* RoMan Deliverable

- Industry-wide guidelines or “white-paper” addressing the manufacture of critical features in high energy rotors
  - e.g.: “Industry Guidelines and Standards for Hole Making Process”
  - Report expected to be used as input for FAA Advisory Circular (AC)
- Key areas of white paper:
  - Process qualification and control of process changes
  - In-process detection of events
  - NDI and disposition of anomalies
- White paper <u>will</u> focus on:
  - Minimum required standards
  - “What shouldn’t be done”
  - Recommended Best Practices
- White paper <u>will not</u>:
  - Dictate specific “how to” manufacture a critical feature
  - Prevent technical innovation or suppress competitive edge
  - Limit processes - not to specify tools / machines

Process Qualification and Control of Changes

- <Opportunity for each sub-team to provide one page vision and strategy for their efforts>

In-Process Detection of Events

Disposition of Anomalies

* Benefits of Rotor Manufacturing Initiative

- Leverage industry knowledge and resources
  - Avoidance of “repeat” problems among industry members via sharing of “Lessons Learned”
  - Access to FAA/European R&D funds for development of improved manufacturing processes/controls
- Facilitate utilization of high strength materials to fullest capabilities
  - Lighter weight, more cost effective part designs through full-utilization of material capability
  - Promoted via defect free manufacturing processes
- Raise industry standards
  - Improved safety from common requirements applicable to all critical rotating part manufacturers Including after market suppliers
    - Reduced likelihood of introducing manufacturing induced defects into field and their associated costs
  - More efficient global part sourcing due to establishment of minimum industry standards applicable to all sources

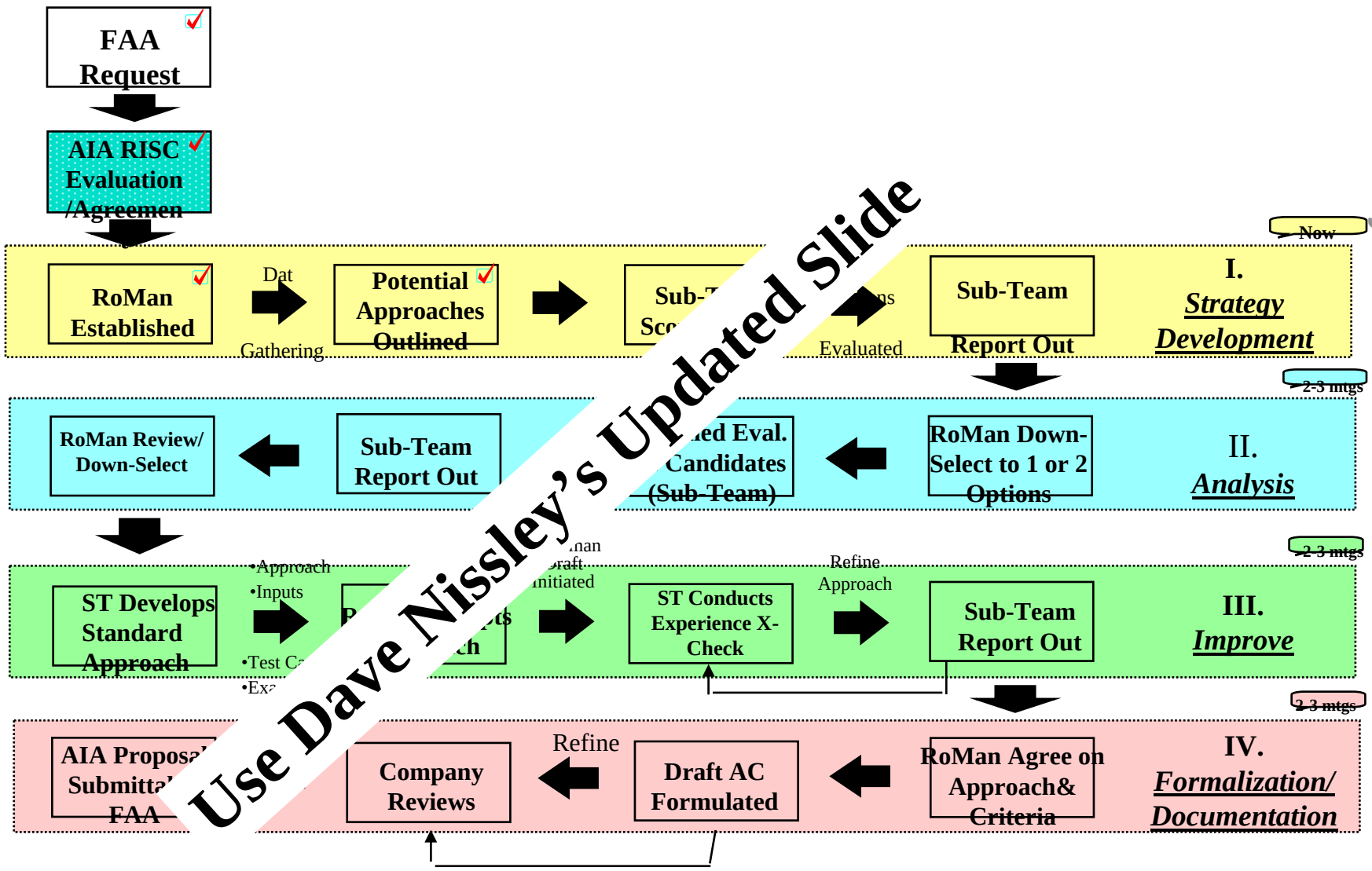
* Impact on Industry

- All suppliers of critical rotating parts will be expected by the FAA to have systems meeting intent of Advisory Circular (or equivalent)
- Minimal impact foreseen in administrative areas of process qualification and control based on survey of existing practices
- Special cause detection capability, if required as part of minimum standards for producing rotating parts, could affect plant and equipment costs
- Potentially offset by other benefits (reduced scrap, etc.)
- Changes in NDI philosophy could result in new inspections being required

* Impact on “…..” Company

- <Company specific information created by respective RoMan team member>

RoMan Roadmap and Schedule



* Summary/Conclusions

- Rotor Manufacturing Committee (RoMan) commissioned Oct.,1998 at the request of the FAA
  - Detailed timing/strategy plans to be completed by 6/99
- Primary areas of focus of RoMan Subcommittee:
  - Process qualification and change control
  - In-process detection of anomalous events
  - NDI and disposition of anomalies
  - Lessons Learned
- Key RoMan deliverable to FAA is position paper facilitating FAA Advisory Circular
- Identified benefits of initiative include:
  - Industry knowledge shared/leveraged in rotating part manufacture
  - Utilization of high strength materials to their fullest capability
  - Industry standards raised in key areas of critical part manufacture

Appendices

- Jay Pardee (FAA) letter
- Member Company experience
  - GE
- Vendor experience with power monitoring
  - Caval Tool

GE Experience with Hole-making Specification

- TBD

Supplier Experience of Power Monitoring

(Based on comments from Les Nadalski - Caval Tool)

- Ease of incorporation
  - Approx. $25K of capital plus minor revisions to N/C programs
- Type of information gathered
  - Amperage & spindle torque
- Usefulness of data gathered
  - Comparison across material types
  - Determines range of process parameters
  - Starting point for other/new parts
- Impact to the process/company
  - Torque - Important to avoid abusive machining. Machine will automatically shut off if the cutter is overloaded.
  - Better control of cutter life. Can easily determine how much cutter life remains
- How Utilized
  - Slowly incorporating on all milling/drilling machines
  - Older machines combined with new controllers

FAA Requested AIA Initiative: Rotor Manufacturing of Critical Rotors

- Background (Brief What why who)
  - Overview:/FAA Rotor Manufacturing Effort
  - Industry Experience: Drivers, Industry Perspective, FAA/RISC Charts: magnitude of problem,
  - FAA/AIA Overall Strategy - Challenge to Rotor Mfg. Subcommittee
- Roman- **Rotor** **Man**ufacturing Subcommittee:
  - What is it, Charter, Work Structure, etc
  - Roadmap/Schedule
- Roman Goal/Deliverable
  - What it is and what it is not
  - Proposed Outline
  - 3 Major Elements
- Benefits
- Impact
  - On Industry
  - On Company (Company Specific place holder)
- Summary/Conclusions
- Appendices
  - FAA (Jay Pardee) letter to AIA
  - Case Studies: Volvo; GE etc.(Cost to implement, infrastructural challenges, benefits, etc.)
  - Suppliers/Vendor testimonies

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Buy-In Team Review Draft 3/15/99

Background:
FAA/AIA Challenge to Rotor Mfg. Sub-Committee

- Define current “Best Practices”
- Define Process Control methodology
- Develop plan for Continuous Improvement
- Increase awareness of feature criticality

White Paper: Proposed Outline

- Introduction
- Recommended Practices/standards
  - Process Qualification And Control Of Process Change
  - In-process Detection Of Events
  - NDI and Disposition Of Anomalies
- Summary