Aerospace Industries Association
Rotor Manufacturing Project (RoMan)

TOGAA
Summary

February 19, 2002

Outline

- **Background**
- **FAA Perspective**
- **Team Membership**
- **Charter & Vision**
- **Impact**
- **AIA RoMan Report Overview**
- **Technology Shortfall Whitepaper Status**
- **Going-Forward Plan**
- **Summary**

Background

- Modern engines have excellent reliability and safety records
  … but uncontained disk failures do occasionally occur

- Industry and FAA have been working to reduce these failure rates
  …with some measure of success
  - Over the past 5 years, 66% drop in rate of events that hazard the aircraft
  - But effects 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) are trending down

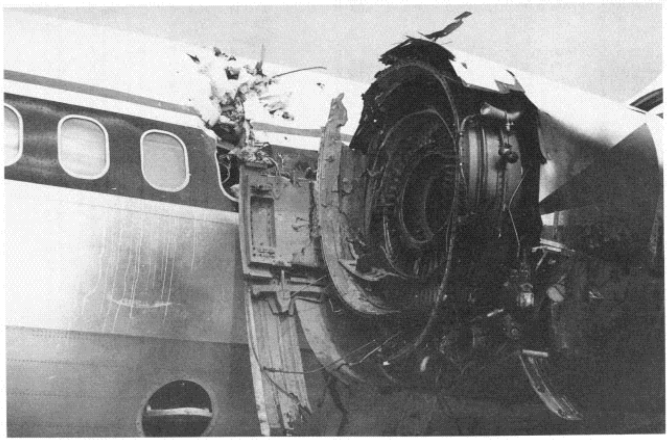
- Engine Manufacturers recognize the need to address manufacturing induced anomalies… and are working to establish minimum standards and recommended practices.

Background - The Pensacola Event

ACCIDENT

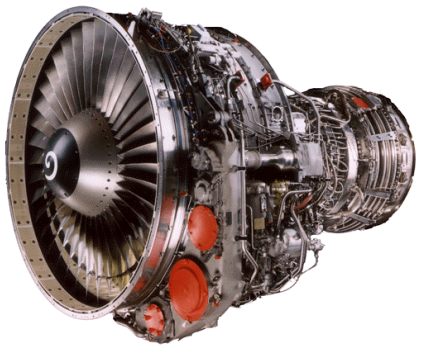
DL 1288, July 6, 1996 - Pensacola, Florida

- MD-88 engine failure on take-off roll
- Pilot aborted take-off
- Stage 1 Fan Disk separated; impacted cabin
- Cause: machining induced anomaly in a bolthole
- 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



- Represented second major premature failure of a Stage 1 fan disk in recent years due to unanticipated and undetected damage
  - ✈ Focused RISC activities on Surface Damage Tolerance methodology development
  - ✈ Spawned FAA Enhanced In-Service Inspection and **Rotor Manufacturing** Initiatives

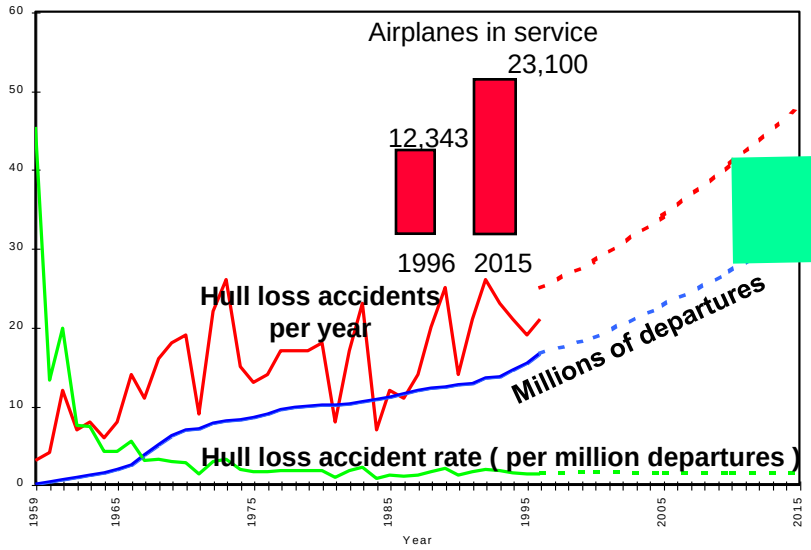
Background - Post Pensacola



- Industry moves to address manufacturing induced anomalies
- Initial focus: holes
- Further work based on results of OEM manufacturing data review

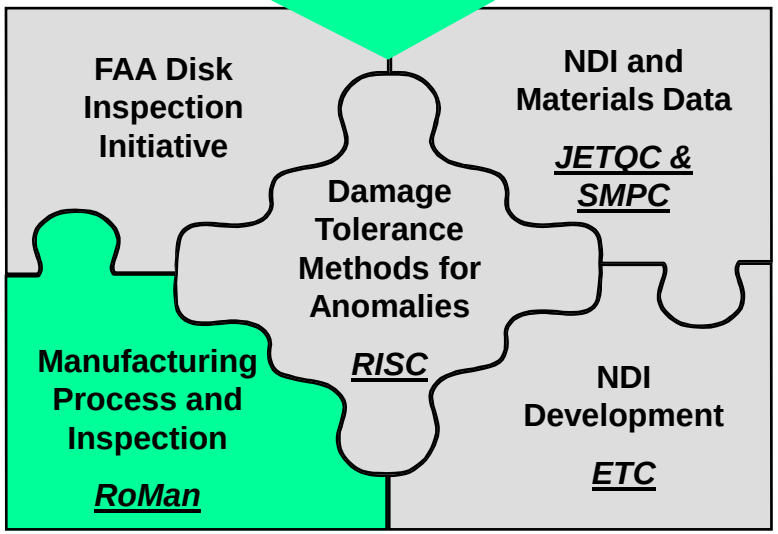
FAA Perspective

Without Intervention, Projected Traffic Growth Will Result in an Unacceptable Number of Accidents



Industry / FAA teams working to reduce accidents

RoMan Fills the Manufacturing Gap



A reduction in manufacturing induced anomalies is required to compliment the damage tolerance philosophy for commercial engines

Team Membership

- **Fiat**
- **GEAE**
- **Hamilton-Sundstrand**
- **Honeywell**
- **MTU**
- **P&W**
- **P&W - Canada**
- **RR-Corp**
- **RR**
- **SNECMA**
- **Volvo**

<u>Company representation:</u>
Manufacturing focal person with Engineering, Quality and NDE support

Excellent synergy with AIA RISC through personnel from P&W, RR and MTU

Charter: Establish industry guidelines that improve manufacturing, engineering and quality practices towards eliminating manufacturing induced anomalies in critical rotating parts.

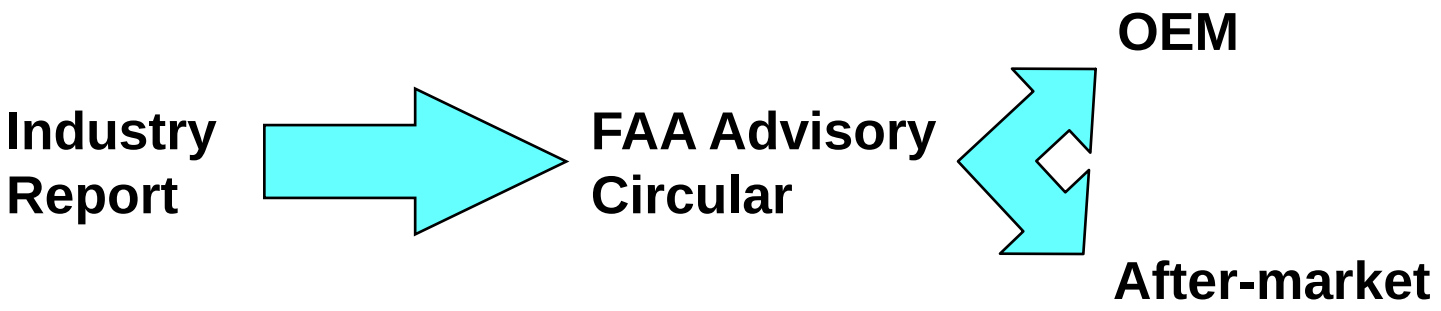
Vision: Minimize manufacturing induced anomalies in critical rotating parts.

Minimum Standards
Recommended Practices
(Do's & Don'ts)

Dictate tooling or process
Prevent innovation
Reduce competitive edge

Guidelines documented in industry report

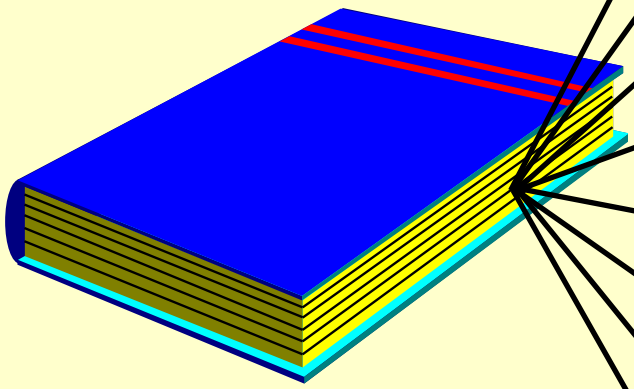
RoMan Guidelines Will Impact Rotor Manufacturing



- **FAA will expect ALL suppliers of high energy rotating components to comply with the intent of the Advisory Circular**
- **OEM administration of process qualification and control minimally impacted**
- **In-process detection of anomalous process events, if required, may affect plant & equipment costs**

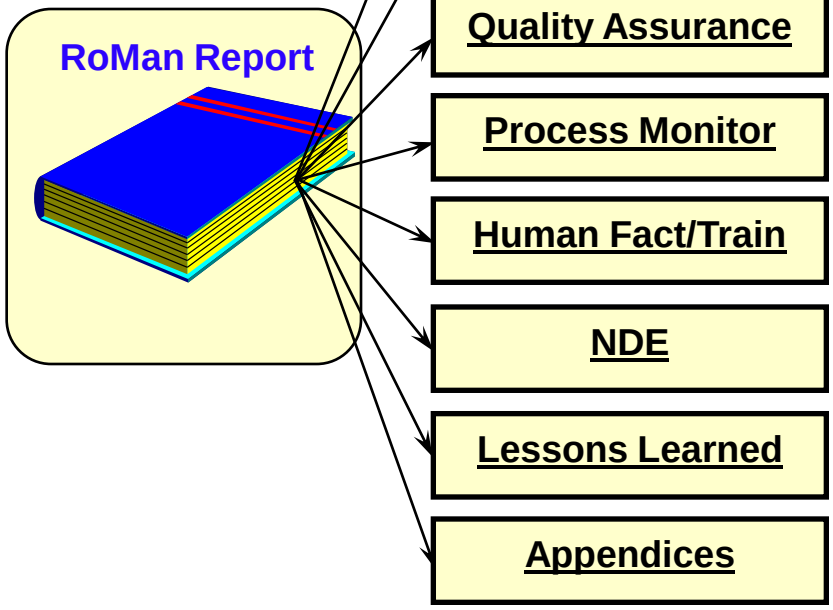
RoMan Report Content Agreement Reached 1/02

RoMan Report



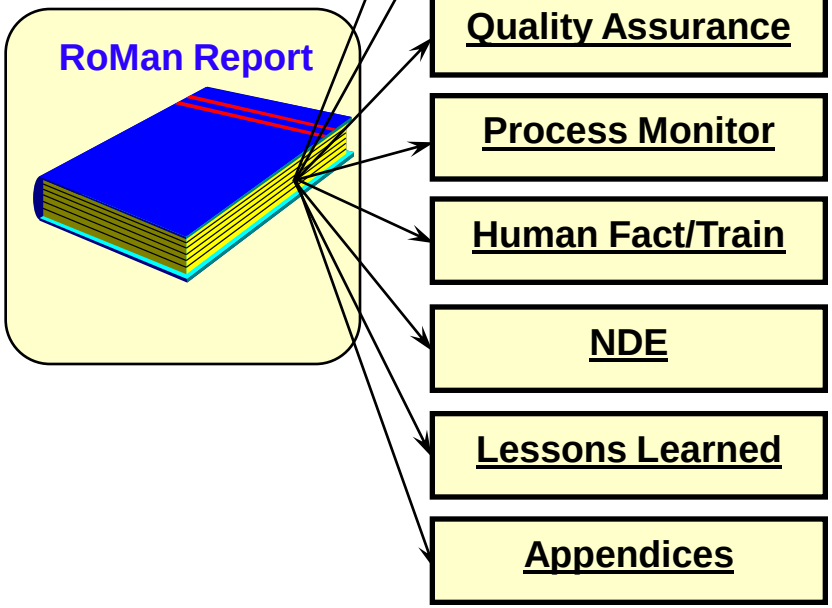
- **Recommendations**
- **Integrating Mfg into Overall Part Integrity**
  Mfg Process Validation Requirements
- **Quality Assurance**
  Skill mix requirements for material review
- **Process Monitoring**
  Required for “high risk” holes
- **Human Factors & Training**
  Guidelines for awareness & training
- **Non-Destructive Evaluation**
  Guidelines for selecting an appropriate NDE
- **Lessons Learned**
  Focuses on holemaking mfg experience
- **Appendices**
  Process monitoring of holemaking & NDE

Overall Recommendations



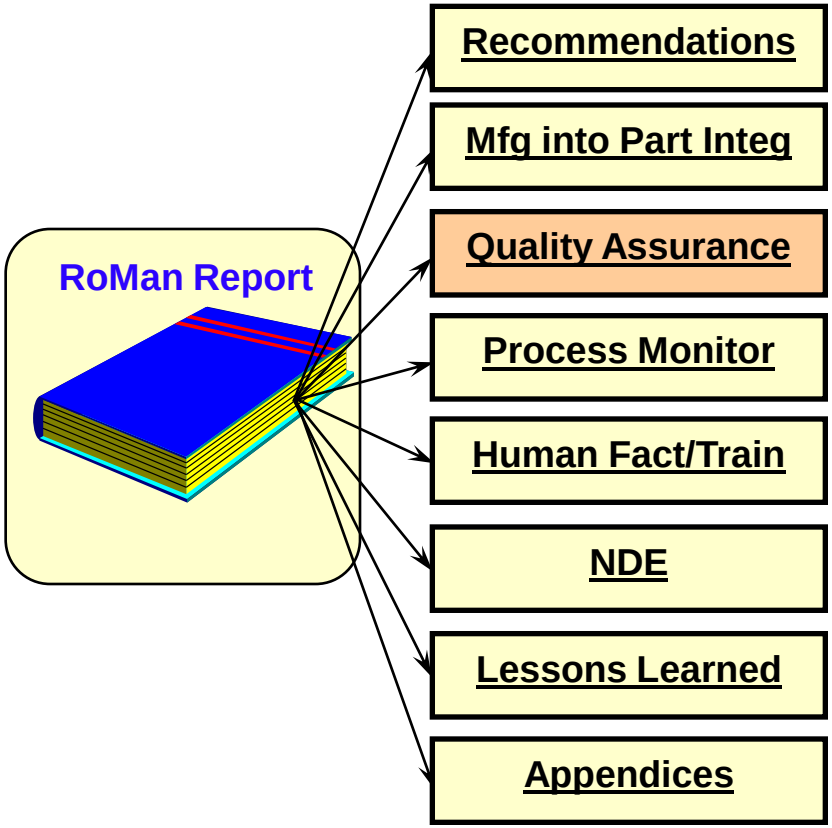
- Convey the part criticality to all parties involved in the part manufacture
- How to perform mfg process validation including skill set requirements
- Rollup mfg steps and methods into a Manufacturing Control Plan
- Educate and train personnel
- Holemaking is a sensitive mfg process
  - Use process monitoring for "high risk" holes (e.g., holes selected per RISC method)
  - Use appropriate NDE method with attention to high L/D holes
- Perform research in:
  - Process control
  - Process monitoring
  - NDE

Integrating Mfg into Overall Part Integrity



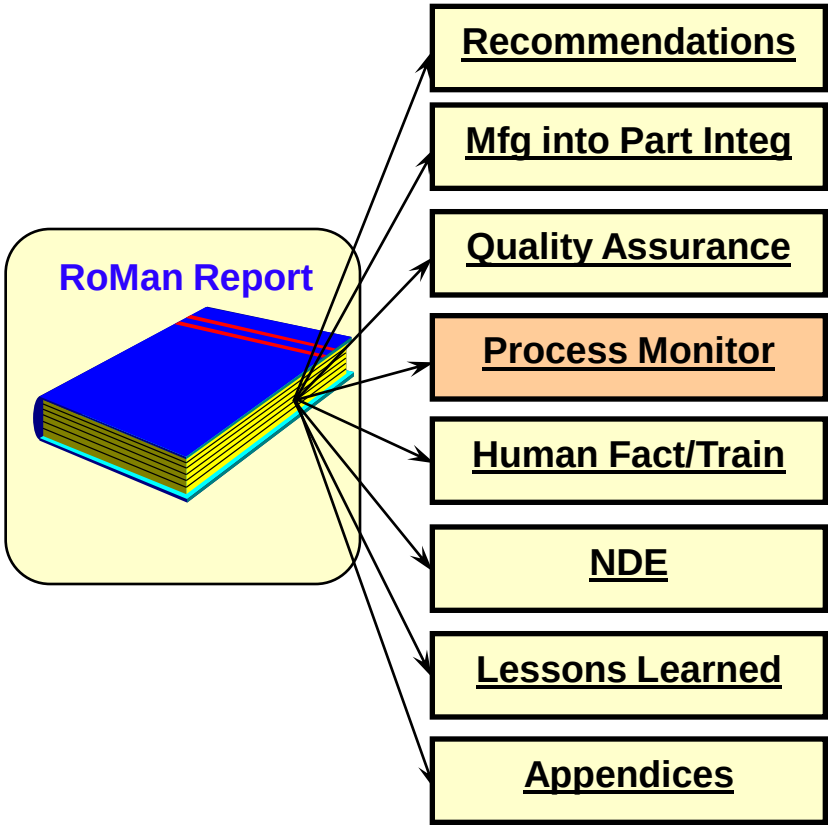
- Use part and/or feature designation(s) to convey the need for special manufacturing controls.
- Achieve process validation via part specific or generic manufacturing approaches established by the Process Validation Function (PVF) team.
- Guidelines provided on the types of data needed for process validation …focused on the fatigue capability
- How to identify substantial mfg process changes…and how to perform process change validation.

Quality Assurance



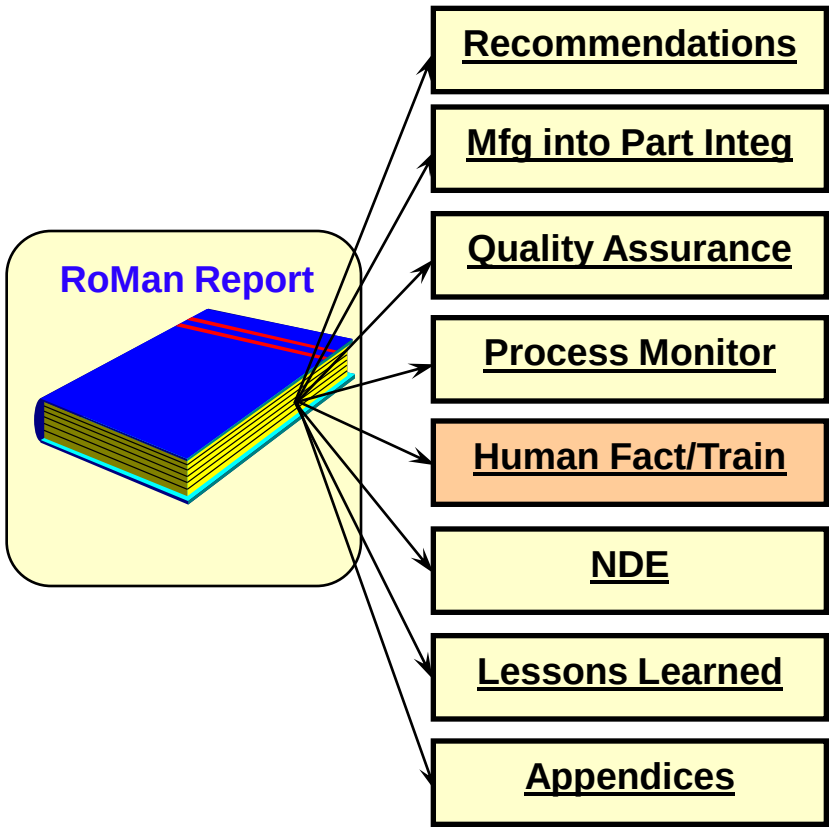
- Use written work procedures that seek to prevent non-conforming parts from entering service.
- Perform periodic audits to ensure compliance with the manufacturing control plan.
- Identifies skill set for material review and non-conformance disposition.

Process Monitoring



- Introduction on how machining induced anomalies can be created.
- Guidance on how process monitors can be used to detect machining induced anomalies including setup, calibration and anomaly detection.
- Process monitoring production demonstrated and recommended for "high risk" holes….other processes TBD

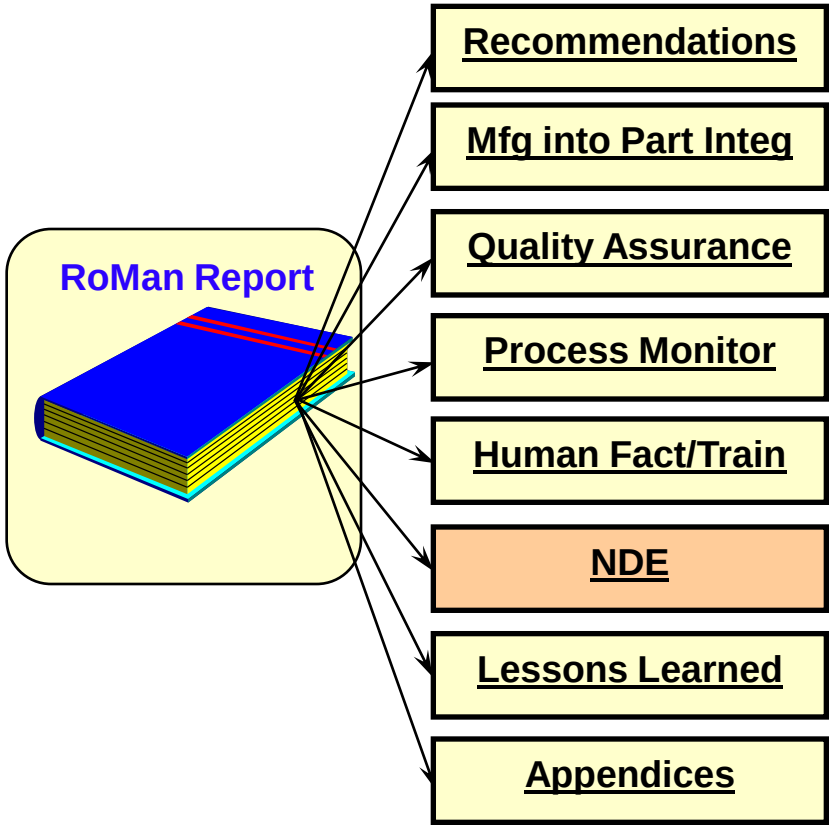
Human Factors and Training



- Human observation is a valuable tool for maintaining mfg process capability and consistency.
- Appropriate mfg atmosphere and culture is beneficial.
- Training can help minimize machining induced anomaly creation and should include:
  - The importance of remaining within validated mfg process parameter limits per the mfg control plan
  - Change control process
  - Process monitoring equipment involved

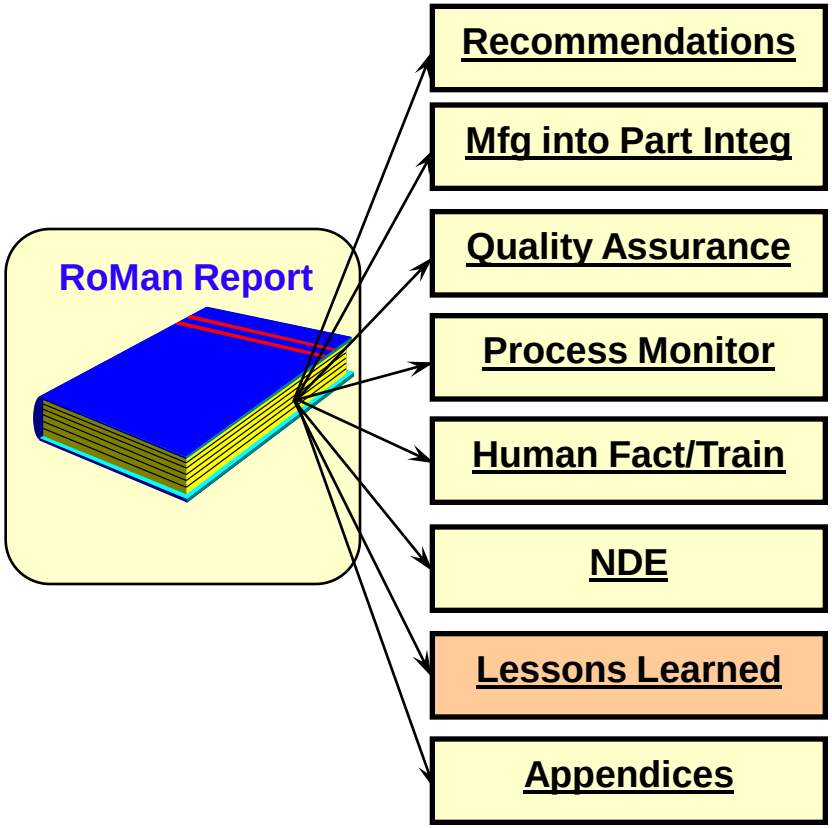
Non-Destructive Evaluation

MTU "guidebook" full of practical experiences is available



- Discusses available NDE techniques and how to:
  - Choose an appropriate NDE method
  - Determine NDE reliability
  - Improve anomaly detection capability
- Provides NDE capability matrix for detecting anomalies in low L/D and high L/D holes (etch, visual, FPI/MPI, ECI).

Lessons Learned



Discusses experiences in holemaking including process monitoring and observations from a titanium holemaking study on anomaly creation and detection.

RoMan White Papers Address Technology Shortfalls

- **Lessons Learned (Anomaly) Database – completed; awaiting non-disclosure coverage under FAR Part 193 prior to industry data submittal**

- **Visual Inspection (NDI) – in queue for FAA funding**
  - **Improved (automated) optical techniques**
  - **Laser-Scanning - holes**

- **Process Monitoring – in queue for FAA funding**
  - **Acoustic Emission - potential for small diameter holes and other mfg processes**
  - **Vibration – potential for holes and other mfg processes**

- **Improved automated probes (NDI) for anomaly detection – in queue for FAA funding**
  - **Array/Flex and Absolute ECI**
  - **Advanced motion control**
  - **SQUID**
  - **Jentek system**

- **Relationship Between Anomalies and Fatigue Life – European led MANHIRP program underway**

Lessons Learned Database

- Central location for all OEM manufacturing induced anomaly data
- Provide manufacturing process details which led to anomaly
- Provide industry with the means to avoid anomaly re-occurrence
- Data source supporting RISC manufacturing induced anomaly surface damage tolerance effort

Closure of RoMan Project is pending report submittal to AIA PC…but team will remain active under RISC

- Report content complete, Jan ’02
  - Submit to AIA PC 1Q02
- Lessons Learned Database – series of telecons setup through 2002
  - Oversee database population
  - Review database content
  - Develop recommendations from database review
- RoMan team meets under charter of RISC (Jan 2003)
  - Review recommendations from database review
  - Status on-going technology development programs (MANHIRP, etc)
  - Disposition comments on report from AIA PC or others

Summary

- **AIA Rotor Manufacturing Project (RoMan) working since 10/98 to provide guidelines on rotor manufacturing best practices**
- **RoMan reached team consensus on report material 1/02**
- **Technology shortfalls identified, prioritized & working**
- **Team going-forward plans and objectives identified and agreed**
- **Benefits of establishing rotor manufacturing guidelines include:**
  - **Improved flight safety by raising industry rotor mfg standards**
  - **Industry knowledge shared / leveraged**