NASA Aviation Safety Program (AvSP)
System-Wide Accident Prevention

Maintenance Human Factors

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Introduction: Maintenance Human Factors

Challenges

- Maintenance error often latent, difficult to identify and track
  - Lack of human factors database
  - Risk assessment tools
- Increasingly difficult to ensure adequate maintenance in an environment of:
  - Deregulation, competitive pricing, economic cutbacks
  - Increased outsourcing of work
  - Increased complexity of hardware/software systems
  - Aging fleets
  - Training out of sync with technologies
  - Shortage of qualified maintenance personnel

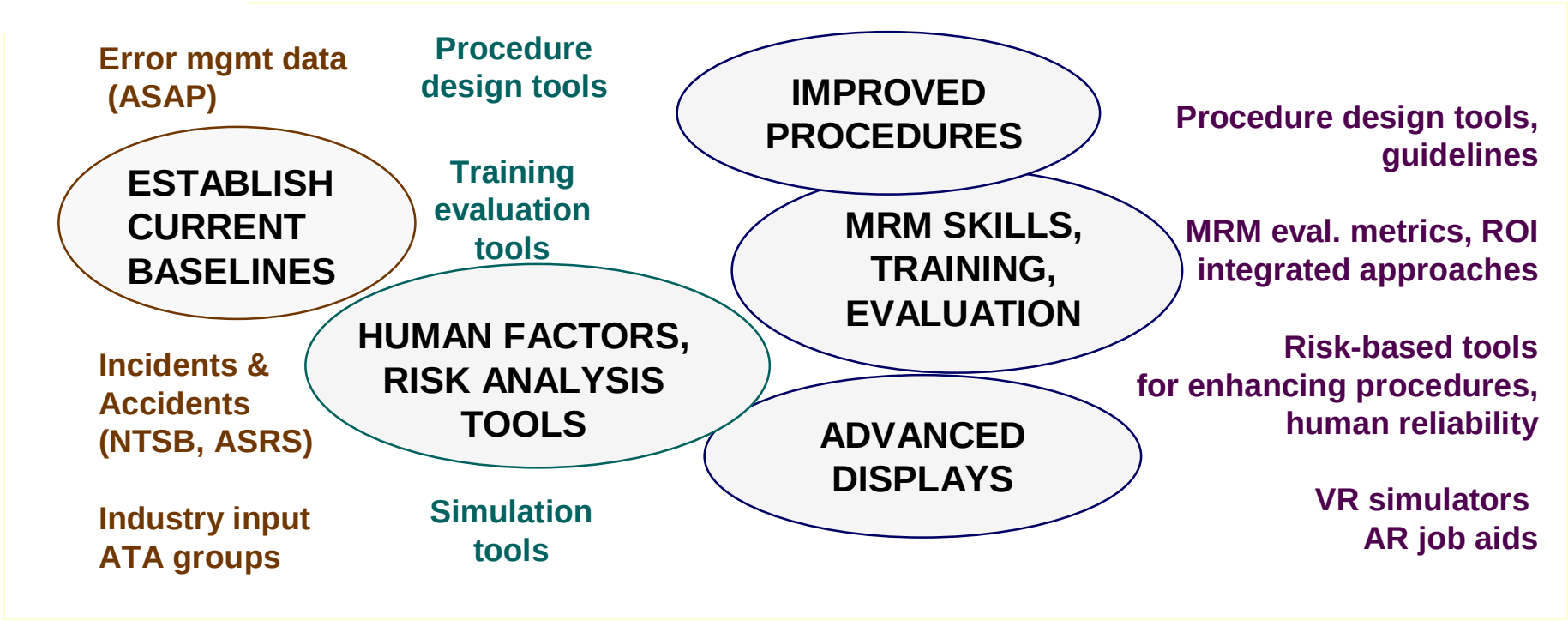
Introduction: Maintenance Human Factors

- Goals: Development and provision of guidelines, recommendations & tools directly to maintenance personnel and managers, through --
  - Better understanding of human error and human reliability associated with maintenance and inspection tasks
  - Development of interventions and task aids that reduce human error and enhance safety and effectiveness
- Approach: Continuous involvement of operational partners through all phases
  - Identification of maintenance human errors
  - Definition of HF requirements and risks
  - Development of techniques & tools; HF interventions
  - Operational validation & implementation

Program Elements

- Maintenance Error Baselines
  - Inhouse: Crew Factors Group
- HF Risk Analysis Tools
  - University of Idaho
- Advanced Displays (VR & AR)
  - Clemson University
  - Boeing, Huntington Beach
- MRM Skills, Training & Evaluation
  - Santa Clara University
  - Naval Postgraduate School & Navy Safety Center

Program Elements & Approach



Maintenance Error Baselines

- GOAL: Establish current maintenance error baselines in order to identify safety needs. Re-visit the NASA ASRS database in response to a significant increase in ASRS reporting.
  - ~200 reports during 1993-1998
  - ~800 reports during 1999-2000
- OBJECTIVES
  - Update ASRS incident summaries applying various typologies
    - MEDA (Boeing): Emphasis on procedural errors (~44%) and related factors (e.g., the document itself, time constraints, insufficient technical support)
    - HFACS-ME: Focus on context, management, maintainer & workplace conditions
- TOOLS: A standard relational database for future analyses supporting
  - multiple coding strategies
  - direct links from one set of analyses to another
  - data transformations required for text analysis of narratives (QUORUM/PERILOG)
- STUDIES IN PROGRESS
  - Analysis of procedural errors
  - Shift handover
  - MEL document
  - MX log
  - Time pressure
  - Relationship between error types and preconditions

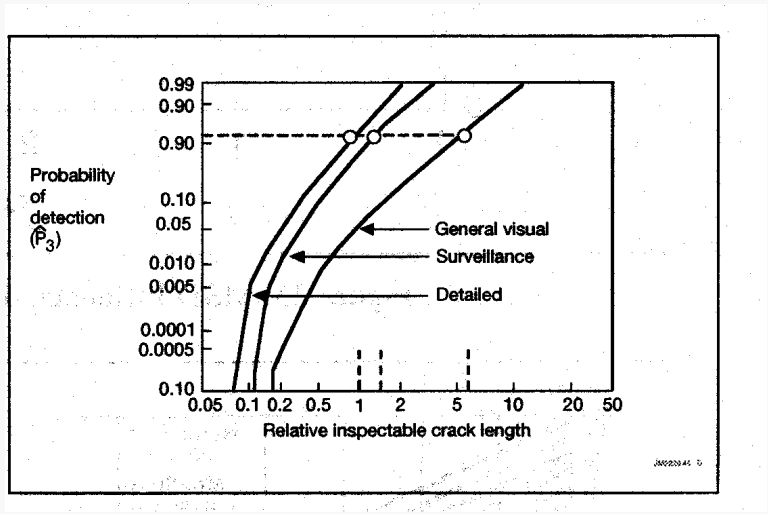
San Jose State Univ Fndn – Batelle, ASRS
Partner: ATA MHF subcommittee, ASAP operators

Ames Research Center

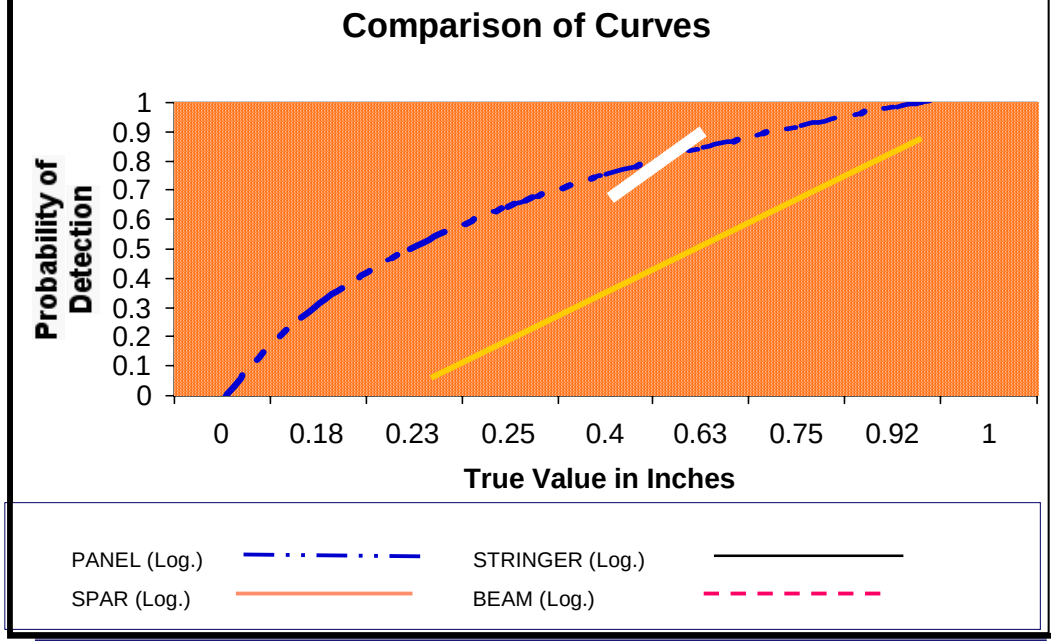
HF Risk Analysis Tools

- GOAL: An enhanced inspection program through optimized inspection points, intervals, training, and resource allocation
- APPROACH: Risk-based methods for determining actual inspection reliability; based on Boeing crack propagation curves and actual inspection data
- PRODUCT: Develop software tool to use actual reliability estimates for trending: allowing company to track deviations from baselines, tailor inspection training and refine maintenance intervals to leverage strengths and target weaknesses
- CURRENT STATUS
  - Collected and characterized inspection data from 4 fleets (747, 757, DC9, DC10), binned into 5 categories (panel, lug, beam, stringer, spar)
  - Demonstrated methodology for determining actual probability of detection (POD) curves from 500 B-747 data points and comparisons to mfg estimates
  - Completed a study of crack measurement vs. inspector estimation
- NEXT
  - Develop & validate software tool per airline specifications
  - Application to other areas (e.g., corrosion)

L. Ostrom & C. Wilhelmsen, University of Idaho
Partners: Boeing, Northwest Airlines



Boeing Inspector Reliability Curves are used as part of the basis for developing damage tolerance-ratings and determining inspection and maintenance interval requirements



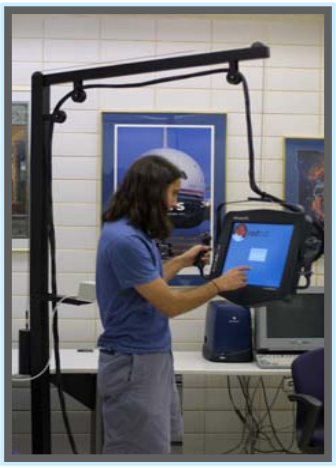
This set of curves represents ACTUAL probability of detection for 4 types of cracks. Data represent more than 500 data points from a B747 fleet. Although these cannot be compared in a simple way to the original Boeing estimates, they are significantly better. This may be due to inspection practices and standards as well as to aspects of the maintenance program (e.g., general visual inspection vs. detailed inspection).

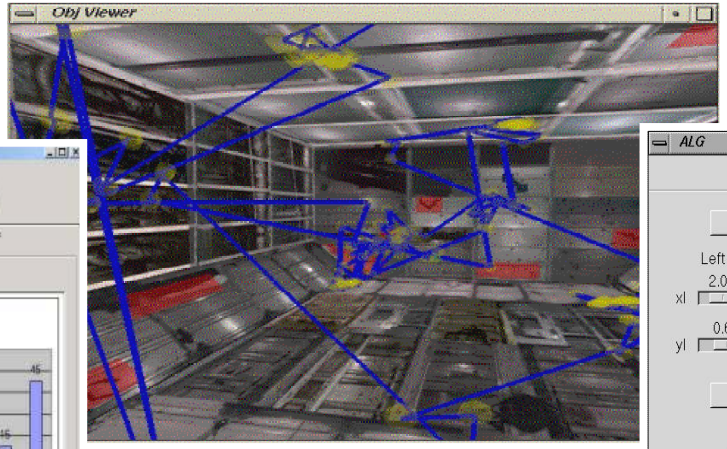
Advanced Displays: Virtual Reality

- GOAL: Develop technologies that augment traditional OJT and aid tasks through enhanced information support
- APPROACH: Virtual Reality (VR) simulator for A/C visual inspection training and for controlled studies of human performance
- PRODUCTS to date
  - VR simulation of aft cargo bay, fuselage, wing with potential defects.
  - 3D eye movement analysis algorithm for collecting eye movement data.
  - Experimental protocol for conducting studies related to the use of feedback and feedforward for inspection training.
- CURRENT STATUS
  - Tested, verified, and validated performance and process (cognitive measures) data collected by the simulator.
  - Developed GUI for presenting feedforward and feedback data on process and performance measures (output measures).
  - Developed scenarios for conducting studies using data collected from industry partners
- Partners
  - DAL, Fed Ex, Lockheed Martin Aircraft Centers, NASA KSC
- NEXT
  - Experiment evaluating various inspection training methods
  - Focus on collaborative OJT

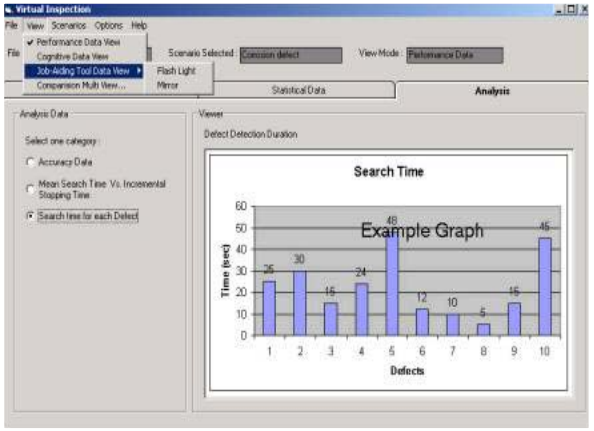
Anand Gramopadhye - Clemson University
Partners: Delta Air Lines, Lockheed Martin Aircraft

VR Simulation Tools

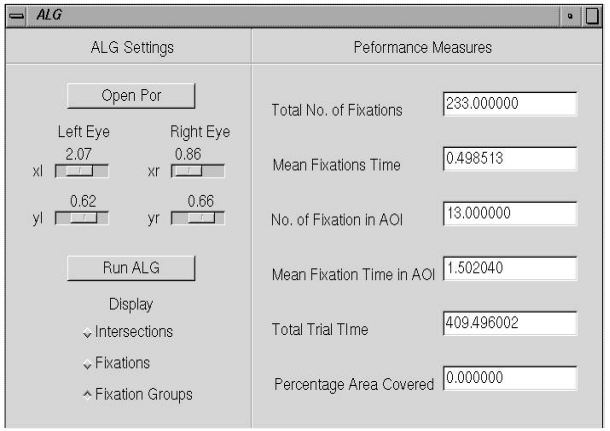




A 3D display for providing graphical cognitive feedback information



Summary of performance data



Interface provides statistical cognitive feedback information

Performance and Process feedback in the VR environment

Advanced Displays: Augmented Reality

- GOAL: Measurement of process improvement achieved when real-time collaboration is supported by an image-based technology

- APPROACH
  - Definition and selection of an implementation testbed (field site plus engineering site)
  - Implementation of devices and processes for collaboration
  - Measurement of system performance used to gauge the effectiveness of the process improvement to the targeted collaboration.

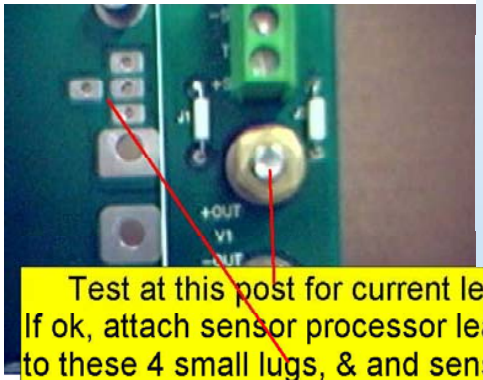
- PRODUCT Benefits
  - Efficient guidance for uncommon tasks.
  - Complement training / compensate for compressed training schedule.
  - Reduce cost of engineering resolutions.
  - Provide views for areas of limited access.
  - Reduce time away from worksite.
  - Provide access to multiple sources of information.
  - Synergy with multiple contributions to a solution.
  - Markup on imagery may be customized for the technician

Anthony Majoros, Boeing, Huntington Beach
Potential Partners: USAF C17

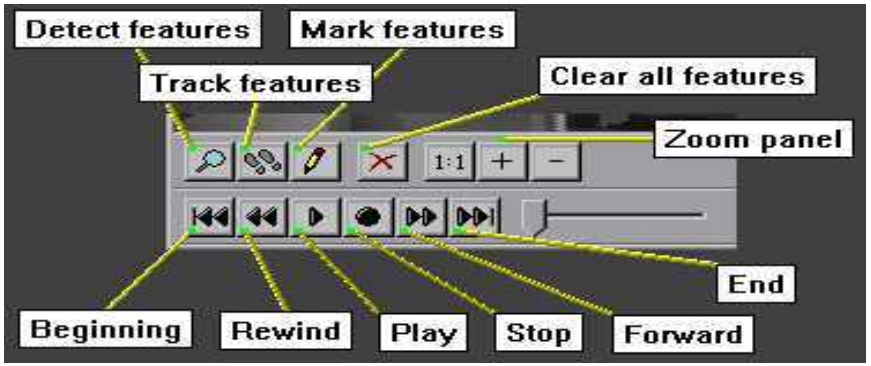
BOEING®

Advanced Displays: Augmented Reality:
Collaborative Engineering Support Tool

Prospective Environments



Remote Collaboration and
Annotated Images:
A Problem-Solving System



Instructions via Annotated Video
VCR-like interface for tracking software
(Neumann & Majoros, 1998)

MRM Skills, Training & Evaluation

- GOAL: Recommendations for developing, implementing & measuring the effectiveness of MRM programs
- APPROACH
  - Historical study of industry MRM programs
    - Jim Taylor, Santa Clara University & Manoj Patankar, St Louis University
  - Case study in applied change
    - John Schmidt, Navy Safety Center and Bob Figlock, Naval Postgraduate School

MRM1: Industry Programs

- Maintenance Resource Management (MRM): first MRM-type program in 1990; Programs from 15 enterprises across 100 cities evaluated since 1991
  - US airlines, Repair Stations, Military
- Data collected
  - Pre-Post Training Surveys (approx 52,000)
  - Interviews and observations
  - Safety Performance Data
  - Paperwork Performance Data

DATA ANALYSIS links survey, observation,and performance
Comparisons made using longitudinal and benchmark analysis

Jim Taylor, Santa Clara University &
Manoj Patankar, San Jose State University

MRM1: Industry Programs (continued)

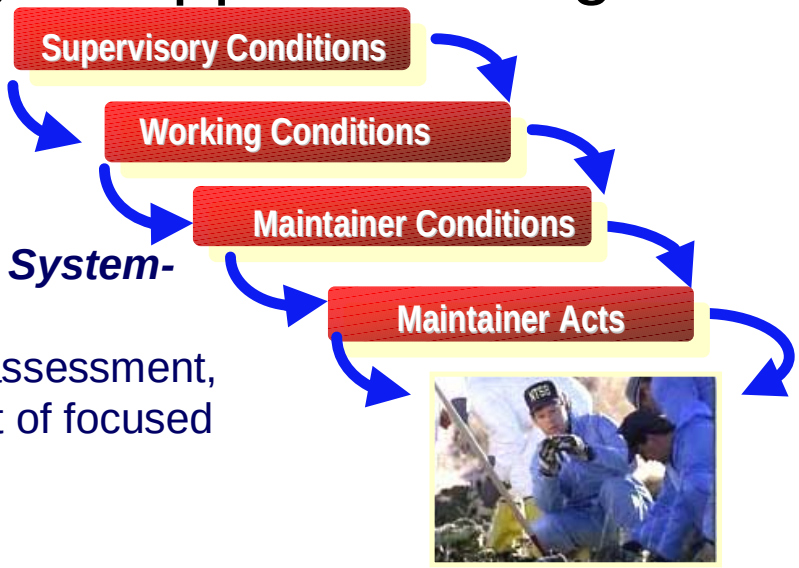
- Goal: Describe and validate the effectiveness of MRM training; to establish safety outcomes
  - Company long term commitment
  - Participants' reactions to MRM training
  - Participants' behavior on the job following training
  - Organizational performance
  - Outcome data as result of behavior changes
- Products
  - Tools for evaluating MRM training effects
  - Guidance for MRM program development
    - Policies for long term commitment
    - Strategic MRM targeting for enhance ROI
    - http://mrm.engr.scu.edu/

MRM2: Case Study in Applied Change

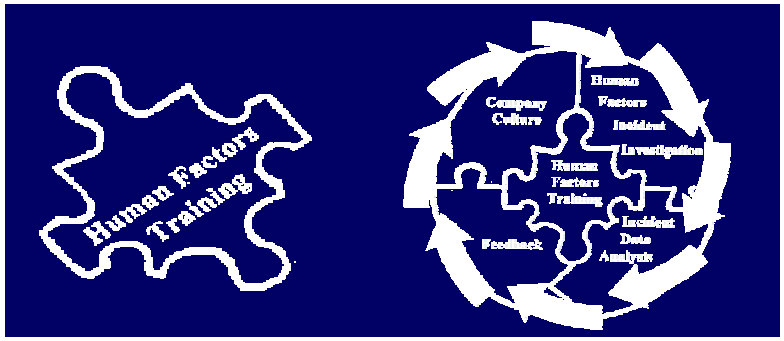
- Goal: Develop an MRM approach grounded in safety data and targeting all levels of the organization
- Products
  - Provide effective reactive and proactive error management
  - Active workforce participation and buy-in at all levels
    - **Incident Data Investigations** and Analysis: Maintenance Extension of the Human Factors Analysis Classification System (HFACS-ME)
    - **Best Practices Benchmarking:** MRM Training with emphasis on Operational Risk Management
    - **Safety Climate Assessment:** Maintenance Climate Assessment Survey (MCAS) based on model of high reliability organizations
- Partners
    - Navy & Marine Corps Aviation Units (VR Wing)
    - U.S. Coast Guard
    - TWA Rework Facility Kansas City, MO
    - Naval Aviation Depot Cherry Point
    - United Space Alliance

John Schmidt, Navy Safety Center and
Robert Figlock, Naval Postgraduate School

MRM2: Case Study in Applied Change (continued)



HFACS-ME
(Human Factors Analysis & Classification System-Maintenance Extension)
developed for the analysis of incidents, risk assessment, foundation of MRM training and development of focused interventions



- **Individual Worker -** Awareness & Skill Development (e.g.. performance, safety, teamwork, etc.)
- **Line Supervisor -** Awareness, Skill Development (see above), Implementation, Investigation, & Reporting
- **QA/Safety -** Awareness, Skill Development (see above), Implementation, Investigation, Reporting, & Metrics
- **Upper Management -** Awareness, Overview of Skills, Implementation, Investigation, Reporting, & Metrics

Summary

- Maintenance Error Baselines
  - The updated ASRS capabilities and series of analyses will help establish the current maintenance error baselines. Future work with ASAP data will further supplement our knowledge base
- HF Risk Analysis Tools
  - Maintenance organizations can greatly enhance their control of resources, management decisions, training, and process improvements through use of risk-based methods of assessing their own human reliability
- Advanced Displays (VR & AR)
  - VR technology can provide an immersive environments for training & evaluating performance and conducting experiments
  - AR technology can enhance real-time. remote information access and online communication and collaboration across teams
- MRM Skills, Training & Evaluation
  - Although MRM training programs have found wide acceptance among the maintenance workforce, long term organizational support has been lacking. Guidelines, metrics, advisory materials are available, but new approaches are needed that integrate MRM into everyday operations, and that are founded on consistent policies and safety culture of the company.