Creating a World Class Safety Culture: Attributes of High Performing Organizations

Presented by:
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Space Systems Group

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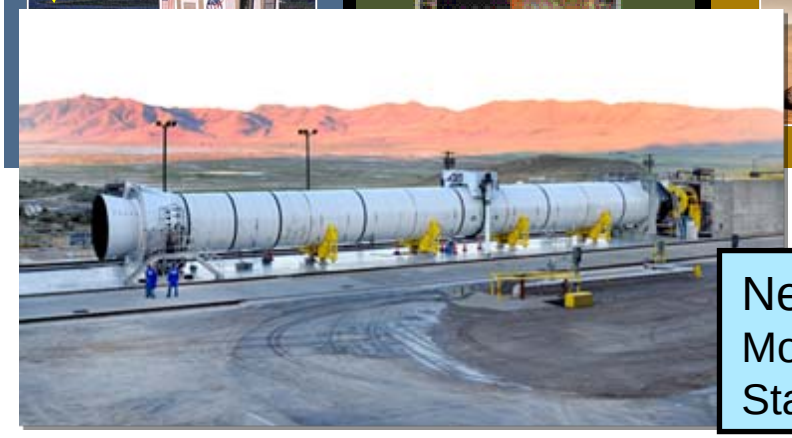
Space Launch Systems

Strategic & Commercial Systems

Spacecraft Systems & Services

Advanced Systems

Space Structures & Components



New Ares Solid Rocket Motor DM-1
Most powerful single engine **ever** built
Static Test Date: August 25, 2009

Lesson Learned Shape our Paths Forward

Lessons Learned = PAINFUL scabs on my backside.

Sources

- Challenger Disaster
- Broad Area Review
- Columbia Accident
- Supplier Quality Escapes
- Significant Safety Events

Common Themes

- Inadequate Process Definition
- Inadequate Process Control and Change Control
- Failure to Follow Procedures
- Failure to Stop Work When Unusual Conditions Encountered
- Innovation
- Lack of Management Involvement
- Inattention
- Lack of Discipline
- Lack of Technical Oversight

Impact

- Failures
- Increased Cost
- Business Lost
- People Hurt
- Building Lost
- Schedule Impacts
- Poor Customer Satisfaction

Actions

- Lean Manufacturing
- Risk Management
- Mission Assurance
- FOD Control
- Process Control
- Process Integrity Audits
- Supply Chain Management

Lessons from Challenger and Columbia

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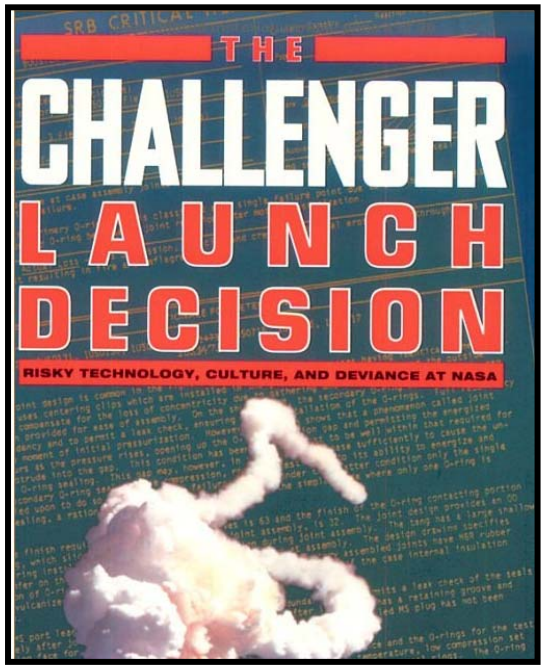

Volume 1, Chapter 8: History as Cause: *Columbia* and *Challenger*

'Leaders create culture. It is their responsibility to change it.'

'Mistake, mishap, and disaster are socially organized and systematically produced by social structures' **Diane Vaughn**

Key Lesson: Engineering teams must clearly communicate the risks to the decision makers:

- Share what they know
- Share what they don't know
- Explain potential outcomes in terms of probability and consequences

Challenger Flight Rationale (January 1986)

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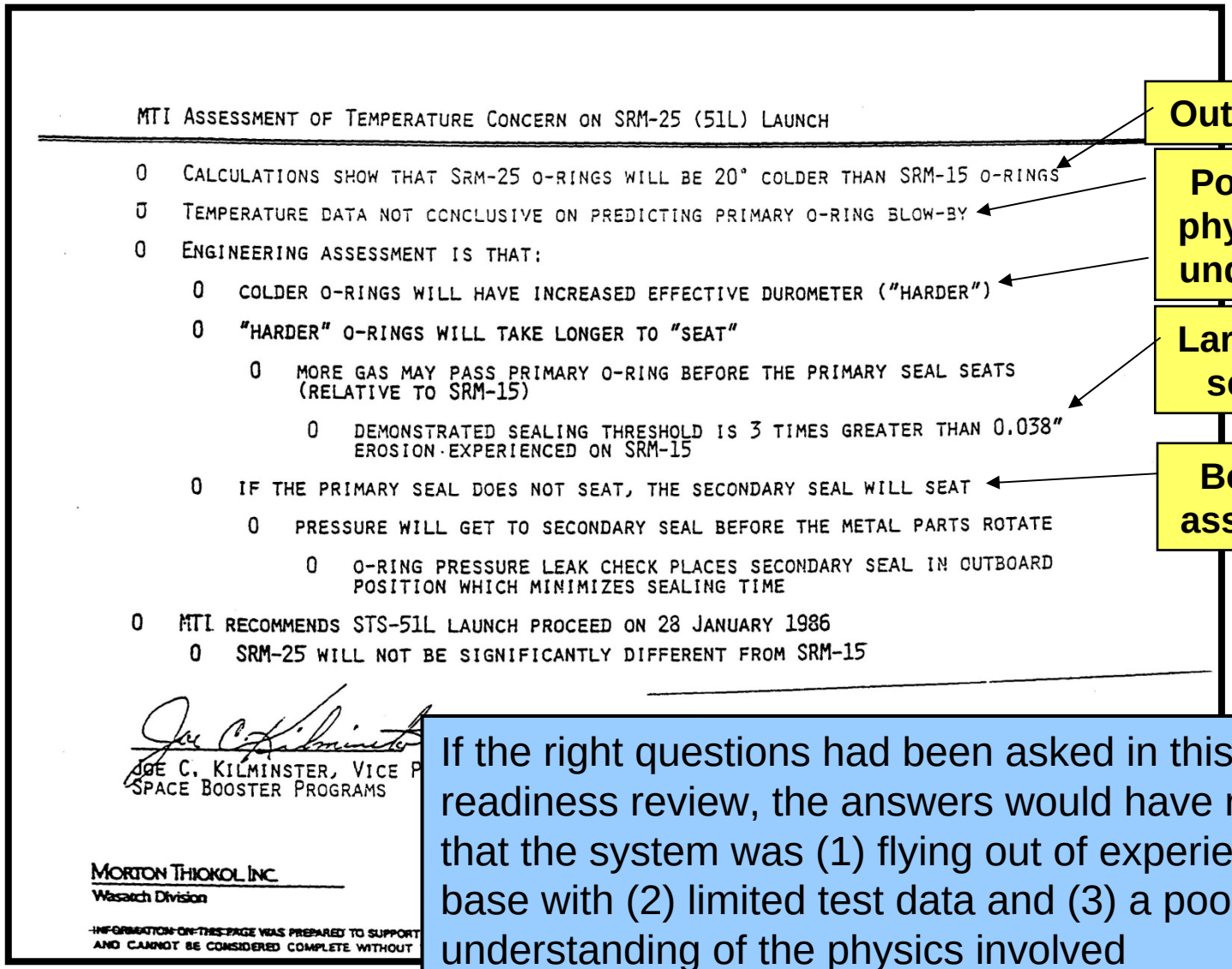


MTI ASSESSMENT OF TEMPERATURE CONCERN ON SRM-25 (51L) LAUNCH

- CALCULATIONS SHOW THAT SRM-25 O-RINGS WILL BE 20° COLDER THAN SRM-15 O-RINGS
- TEMPERATURE DATA NOT CONCLUSIVE ON PREDICTING PRIMARY O-RING BLOW-BY
- ENGINEERING ASSESSMENT IS THAT:
  - COLDER O-RINGS WILL HAVE INCREASED EFFECTIVE DUROMETER ("HARDER")
  - "HARDER" O-RINGS WILL TAKE LONGER TO "SEAT"
    - MORE GAS MAY PASS PRIMARY O-RING BEFORE THE PRIMARY SEAL SEATS (RELATIVE TO SRM-15)
      - DEMONSTRATED SEALING THRESHOLD IS 3 TIMES GREATER THAN 0.038" EROSION EXPERIENCED ON SRM-15
  - IF THE PRIMARY SEAL DOES NOT SEAT, THE SECONDARY SEAL WILL SEAT
    - PRESSURE WILL GET TO SECONDARY SEAL BEFORE THE METAL PARTS ROTATE
      - O-RING PRESSURE LEAK CHECK PLACES SECONDARY SEAL IN OUTBOARD POSITION WHICH MINIMIZES SEALING TIME
- MTI RECOMMENDS STS-51L LAUNCH PROCEED ON 28 JANUARY 1986
  - SRM-25 WILL NOT BE SIGNIFICANTLY DIFFERENT FROM SRM-15

JOE C. KILMINSTER, VICE P
SPACE BOOSTER PROGRAMS

MORTON THIOKOL INC.
Wasatch Division

INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT
AND CANNOT BE CONSIDERED COMPLETE WITHOUT

Out of family

Poor data, physics not understood

Large margins, self limiting

Bounding assessment

If the right questions had been asked in this flight readiness review, the answers would have revealed that the system was (1) flying out of experience base with (2) limited test data and (3) a poor understanding of the physics involved

Columbia Flight Rationale: Bipod Ramp Foam Loss

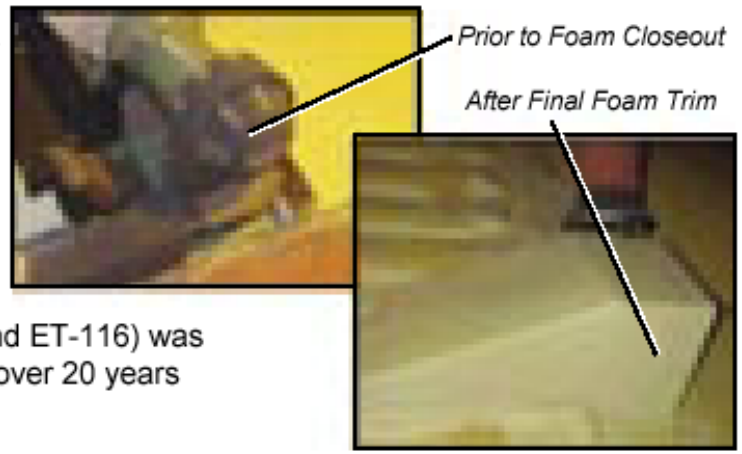
What the chart says:
- Foam has come off before
- It might come off again
- Implies that it probably won't hurt anything

What the chart doesn't say:
- No physics based understanding
- Margins are not addressed
- Potential catastrophic consequences
- Assessment is made on expert opinion, not data

UTTLE PROGRAM
Projects Office (MSFC)
light Center, Huntsville, Alabama

T-115 Bipod Ramp Foam

- **Rationale for Flight**
  - Current bipod ramp closeout has not been changed since STS-54 (ET-51)
  - The Orbiter has not yet experienced "Safety of Flight" damage from loss of foam in 112 flights (including 3 known flights with bipod ramp foam loss)
  - There have been no design / process / equipment changes over the last 60 ETs (flights)
  - All ramp closeout work (including ET-115 and ET-116) was performed by experienced practitioners (all over 20 years experience each)
  - Ramp foam application involves craftmanship in the use of validated application processess
  - No change in Inspection / Process control / Post application handling, etc
  - Probability of loss of ramp TPS is no higher/no lower than previous flights
  - ***The ET is safe to fly with no new concerns (and no added risk)***



Bipod Attach Fitting

Elements of Flight Rationale

- **Technical issue presentations need to address each of the following critical questions:**
  1. Solid physics-based understanding?
  2. Condition relative to experience base (flight or test)?
  3. Margins understood?
  4. Bounding case established?
  5. Self limiting aspects?
  6. Assessment based on data, testing and analysis?
  7. Interactions with other elements?

Elements of Flight Rationale applied in MRB dispositions, change justification, risk assessments, and technical issue presentations at Flight Readiness Reviews.

Check list for presenters and reviewers!

Broad Area Review (BAR)

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The "Space Launch Vehicle Broad Area Review (BAR)", chaired by General Larry Welch in November 1999 was established to:

- Examine recent launch failures and determine causes of the failures

Delta III 259 (August 26, 1998)

- Vehicle ran out of hydraulic fluid while trying to respond to rocket vibrations

Titan IV B-32 (April 30, 1999)

- Centaur upper stage experienced instability during burn resulting in uncontrolled tumbling and improper orbit of payload

Titan IV A-20 (August 1998)

- A short in the power supply wiring harness caused the guidance system malfunction

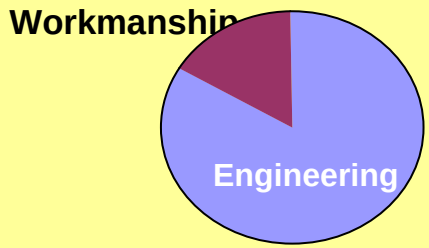
Titan IV B-27 (April 9, 1999)

- IUS Stage 1 failed to separate from Stage 2
- One of six stage 1/2 connectors did not disconnect due to interference with thermal tape
- Engineering ambiguous, engineering intent not understood

Delta III 269 (May 4, 1999)

- Second burn of second stage lasted only 1 second placing satellite in wrong orbit

Failures -- 76% Engineering Caused



Mission Assurance Principles Derived from Lessons Learned

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Lessons Learned: Launch Vehicle Failures

1. **Design process failure**
   - Lack of design robustness
   - Shop floor didn't understand design intent
   - Inadequate technical or physics-based understanding
   - Inadequate process definition

2. **Inadequate systems engineering**
   - Inadequate problem reporting
   - Inadequate postflight assessment
   - Inadequate test like you fly
   - Inadequate independent reviews
   - Lack of formal risk management
   - Inadequate change control

3. **Inadequate manufacturing discipline**
   - Workmanship
   - Unexpected material & process variation
   - Unplanned process changes
   - Inadequate FOD/contamination control

Recipe for Mission Success

- Technical excellence
- Robust designs
- Requirements management
- Process definition and control
- Systems Engineering
- Independent Reviews
- Program planning and execution
- Change control
- Communication to shop floor
- Production planning & execution
- Integrated verification and test
- Risk management
- Learning from our mistakes
- Effective government, industry & supplier partnership
- Experienced & skilled workforce
- Management involvement

Industrial Accident Summary Lessons Learned

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5 fires or explosions at ATK Space Systems 2005 - 2006
•One fatality

15

Common Root Causes

- Inadequate process definition
- Inadequate process control and change control
- Failure to follow procedures
- Failure to stop work when unusual condition encountered
- Innovation
- Lack of management involvement
- Inattention
- Lack of discipline

Actions To Address Root Causes

- Leadership involvement
- Organizational checks and balances
- Standard work (leaders too)
- Technical excellence and process control
- Discipline: Condition of employment to stop and notify supervision

Typical Corrective Actions are Ineffective

- **Problems with our current approach*:**
  1. Tendency to "firefight" the last defect rather than anticipating and preventing the next one
  2. Focus on failures rather than infrastructure issues
  3. Focus on the personal, rather than situational contributions to error
  4. Rely heavily on exhortation and disciplinary sanctions (blame laden)
  5. Do not distinguish between random and systematic error-causing factors
  6. Do not consider human factors regarding error and defect causes

Key Concepts

- **80% of safety incidents involve lack of execution due to some kind of human error or other system related human factors**
- **Working root cause and corrective actions on each and every incident is hopeless**
- **Reacting to quality and safety statistics is like driving while looking in the rear view mirror: it tells you where you've been, but isn't forward looking**

Injuries (defects) are like mosquitoes. It is pointless to deal with them one by one. Others simply appear in their place. The long term solution is to drain the swamps in which they breed: attack the infrastructure issues.*

*Adapted from James Reason, "Managing the Risks of Organizational Accidents", Ashgate, 1997.

Elements of Safety Management

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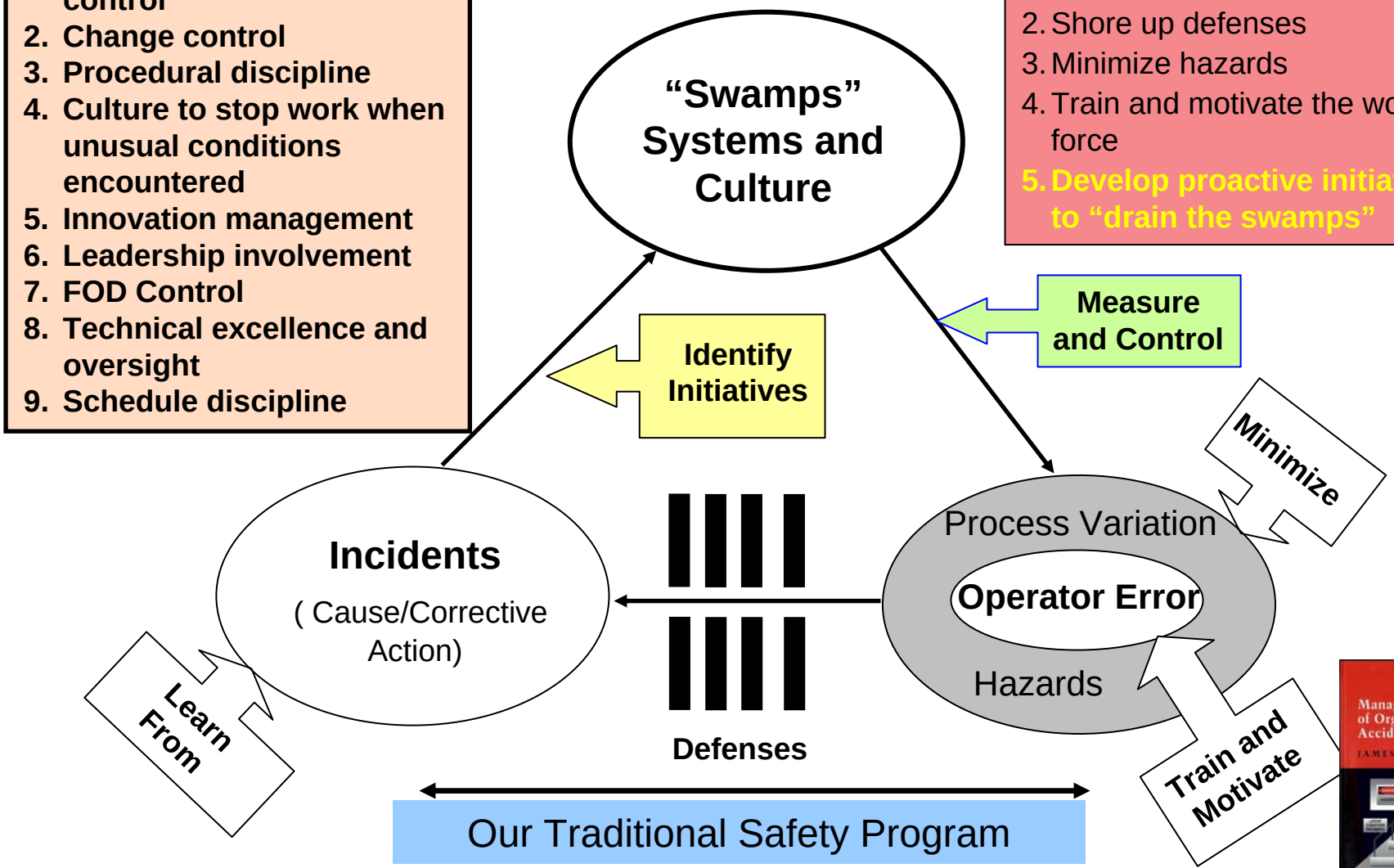
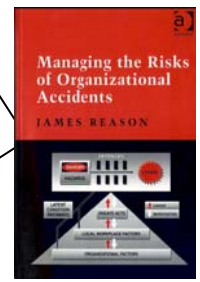
"Swamps"

1. **Process definition and control**
2. **Change control**
3. **Procedural discipline**
4. **Culture to stop work when unusual conditions encountered**
5. **Innovation management**
6. **Leadership involvement**
7. **FOD Control**
8. **Technical excellence and oversight**
9. **Schedule discipline**

Improvement Recipe:

1. Learn from incidents
2. Shore up defenses
3. Minimize hazards
4. Train and motivate the work force
5. **Develop proactive initiatives to "drain the swamps"**





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ATK's Performance Enterprise System (PES)

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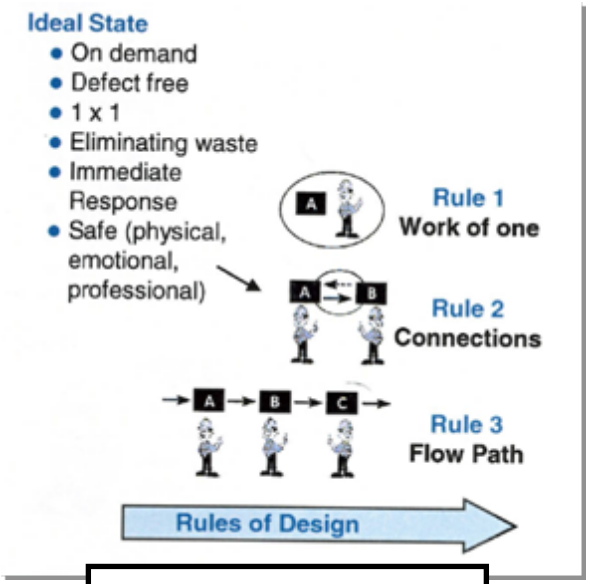
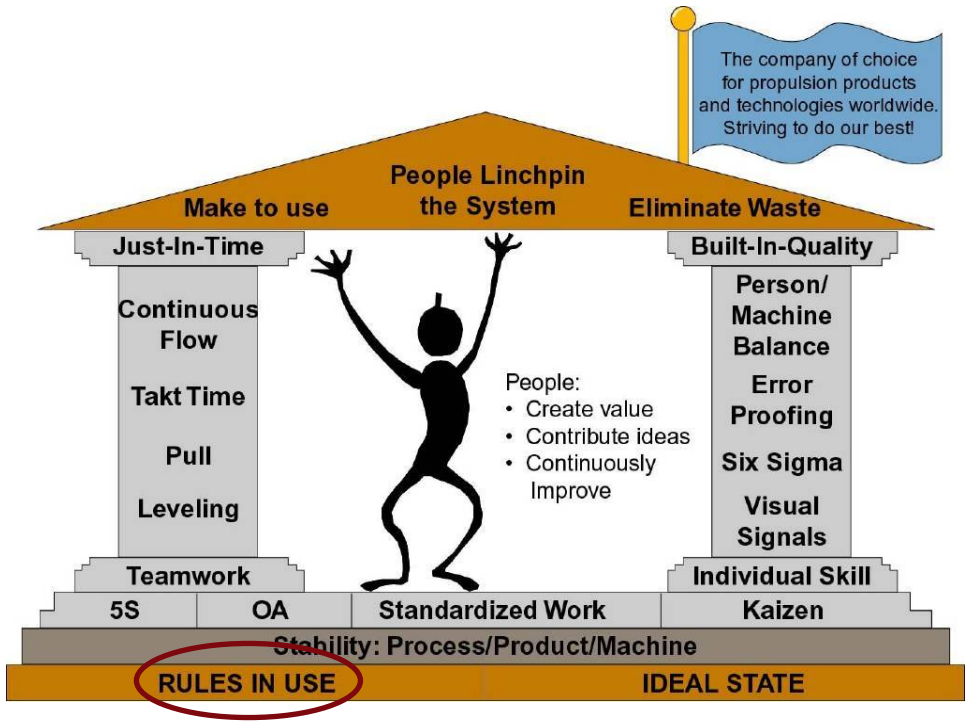


"Rules in Use"

Foundation of the PES House of Quality



Performance Enterprise System

(Based on Toyota Production System)

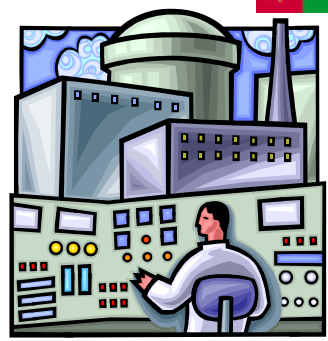
Application of Lean Principles fundamentally changes the work environment, removes the chaos and "drains the swamps"

Attributes of High Performing Organizations

A mountain climber intending to climb Mt. Everest spent years studying the details of every death that had occurred. He learned that there are a lot of ways to get killed. He found it far more useful to study the practices and behaviors of those that were successful and develop a plan that would assure success (planning, training, equipment, routes, etc.) rather than prevent failure.

Attributes of High Performing Organizations*

- **The safety sciences know more about what causes accidents than about how they can best be avoided.**
- **A group of scientists** has addressed this by studying safety successes in organizations rather than their infrequent but more conspicuous failures**
- **These successes involved air traffic control systems, aircraft carriers, and nuclear power plants. These organizations do the following:**
  1. **Manage complex, demanding technologies so as to avoid major failures that could cripple or even destroy the organization concerned.**
  2. **Perform exacting tasks under considerable time pressure.**
  3. **Had carried out these demanding activities with low incident rates and an almost complete absence of catastrophic failures over several years.**



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***Human error: models and management. James Reason**

**Weick KE. Organizational culture as a source of high reliability. *Calif Management Rev* 1987; 29: 112-127.

**Weick KE, Sutcliffe KM, Obstfeld D. Organizing for high reliability: processes of collective mindfulness. *Res Organizational Behav* 1999; 21: 23-81.

Attributes of High Performing Organizations*

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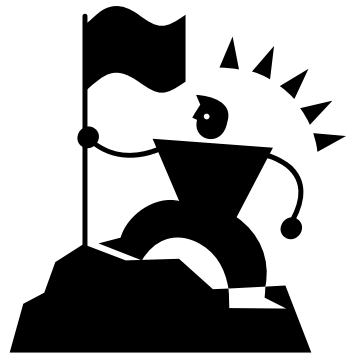
1. **They anticipate the worst and are prepared to deal with it**
2. **It is hard for individuals to remain chronically uneasy, so the organizational culture takes on a profound significance.**
   - Individuals may forget to be afraid, but the culture of a high reliability organization provides tools to help them remember
   - The pursuit of safety is not so much about preventing isolated failures as about making the system as robust as is practicable
3. **High reliability organizations can reconfigure themselves to suit local circumstances.**
   - Routine: they are controlled in a normal hierarchical manner.
   - Emergency: control shifts to the experts on the spot.
4. **Perhaps the most important distinguishing feature of high reliability organizations is their collective preoccupation with the possibility of failure.**
   - They expect to make errors and train their workforce to recognize and recover from them.
   - They continually rehearse familiar scenarios of failure and strive hard to imagine novel ones
   - Instead of making local repairs, they look for system reforms.



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Safety Culture Risk Assessment Tool

An Operations leader said, *"I wish I had a crystal ball that would tell me where the next major accident will occur."*

I said, *"I can't tell you exactly where the accident will occur, but I can tell you what the accident report findings will be."*

Premise:

1. **I believe that I can write the "findings" today for all future accident investigations.**
2. **The fundamental causes of most major accidents are obvious within 2 days of the incident.**
3. **If true, we should be able to identify our high risk areas today, and take appropriate proactive preventative actions.**

Safety Culture Assessment Tool

	Attributes of "At Risk" Organizations	Attributes of High Performing Organizations
Innovation	Technicians use their expertise to "figure it out" and solve problems on their own.	Technicians work literally to approved written instructions. Innovative changes are encouraged, but managed via formal change control.
Process Definition and Control	Processes are loosely defined, "being developed", or tribal knowledge not captured. Process variables not monitored.	Processes are defined, process limits established, off-nominal conditions identified, contingency plans available for process upsets. Critical process variables are defined, measured.
Change Control	Changes are made to "make it better" or "NO" change. Decisions based on judgment and expert opinion..	Changes are reviewed and approved by responsible leadership. "KNOW" change: controlled continuous improvement based on engineering data and analysis.
FOD Control	FOD control means following procedures. FOD control zones and requirements poorly defined.	Work team is passionate about FOD control everyday. Parts, tools and equipment are accounted for, housekeeping is immaculate and 5S is platinum standard.
Culture to "Stop" at Unusual Events	"Unusual" events are common. Culture is to solve problems, when to stop unclear.	Off-nominal or unusual conditions apparent. Requirement to stop as a condition of employment clearly understood.
Frequency of Operations	Infrequent. Once a year or every other year.	Daily

Safety Culture Assessment Tool

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	Attributes of "At Risk" Organizations	Attributes of High Performing Organizations
Technical Excellence and Oversight	Requirements are "tossed over the wall". Engineers only come around after there is a problem.	Technical requirements are defined, translated in shop planning, and executed concurrently. Table Top reviews are the norm. Operators understand "what and why", engineers *know* how requirements are met and verified.
Leadership Involvement	Leadership is on the road, in the office or otherwise disengaged. Leaders not aware of what their people are doing or not available to help when needed.	Leadership has a floor presence. Standard work for leaders in place. Leaders are passionate about execution, excellence and improvement.
Corrective Action	Program has no corrective action board, or board is focused on correcting individual defects.	Program has a formal corrective action board resolving repeat offenders and looking for systemic reforms.
Work Environment and Schedule Compliance	Panics, behind schedule, overtime, backlog. Late engineering. Late planning. Materials unavailable. Stuff happens.	"Cadence". Takt Time. Flow. On schedule. Work planned and executed. Engineering, planning, materials, tooling, people ready when needed. PES embraced and implemented.
Discipline	Get the job done mentality, no matter what. Rules don't apply in this situation. A short cut will save time and no one will know. No one listens to my needs.	Standards (planning, safety rules) are in place and followed. Risks understood. Operator concerns are addressed. Initiatives are in place to prevent and identify process creep.

Safety Culture Assessment Tool

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	Attributes of "At Risk" Organizations	Attributes of High Performing Organizations
Application of "Rules in Use"	Systems are complex Roles and responsibilities unclear Work is chaotic Backlogs are large. Overtime is high.	Work of each person is highly defined Defined process with no forks/loops Customer/supplier communications simple and visual Continuously improved to eliminate waste: help chain is poised to pounce
Implementation of "Pull" system working to Takt	Product produced in batches Materials are purchased to meet sales goals. Problems age, and are complex	Products produced 1 x 1 as needed by the customer. Materials arrive just in time Problems are visible and solved at low levels
Implementation of Standard Work	Everyone does it different. Problems are hard to recognize.	Work is standardized to the best practice for Takt time, sequence, content and expected outcome
Organization and orderliness	Work place is cluttered with stuff you might need someday.	Stuff is sorted, set to order, shined, and standardized to the 5S Platinum Standard
Multi-skilled workers	Everyone is specialized. Things sit if key people are absent.	People are interchangeable. Products and services continue when team members are absent.
Passion for eliminating waste	Defects are common. Things and people are waiting in queue.	Defects are an abomination. Self-tests and error-proofing make defects impossible. Things and people are engaged in value added activities.

Summary

1. 80% of our safety and quality problems are caused by human errors or other human factors
2. Working root cause and corrective action on every incident is like swatting mosquitoes
3. 80% of our problems are related to systems and work culture that leadership has created
4. We need to identify and drain the swamps
5. We need to attack the management systems issues and cultural issues that control how people work
6. We need to be proactive: embrace PES
7. We need to be passionate about excellence in execution
8. We need maintain a healthy fear of failure: plan, anticipate, mitigate