



Replacement of Cr and Cd plating

Partners in Environmental Excellence

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Summary

- ❑ **Drivers and barriers for “green” processes**
- ❑ **Identifying and choosing the alternatives**
- ❑ **Costing the alternatives**
- ❑ **Validating the alternatives**
- ❑ **Qualifying the alternatives**
- ❑ **Getting them used**

Why would you want to replace Cd and Cr?

**The “environmentally-correct” answer:
“Because they are bad for the environment and everyone’s health”**

**The usual answer:
“Why would you want to replace Cd and Cr?”**

**The answer you want to hear:
“Because Cr and Cd are an expensive pain in the neck”**

Drivers for Cd and Cr replacement

Environmental

- Cr⁶⁺ reduction or elimination
- **Weakest driver**
- **BUT European regs getting serious, especially for chromates and Cd**

We are seeing this in commercial LG

Technical

- **Improved performance**
 - Thicker rebuild
 - Less corrosion
 - Less wear
- **Improved maintainability**
 - **Lifetime coating**
 - **Easier, more reliable processing**

USAF LG

GTE issue

Cost

- **Lower cost of ownership**
 - Shorter processing time
 - Processing cost may be higher or lower
 - Longer maintenance cycle

Airlines

Risk

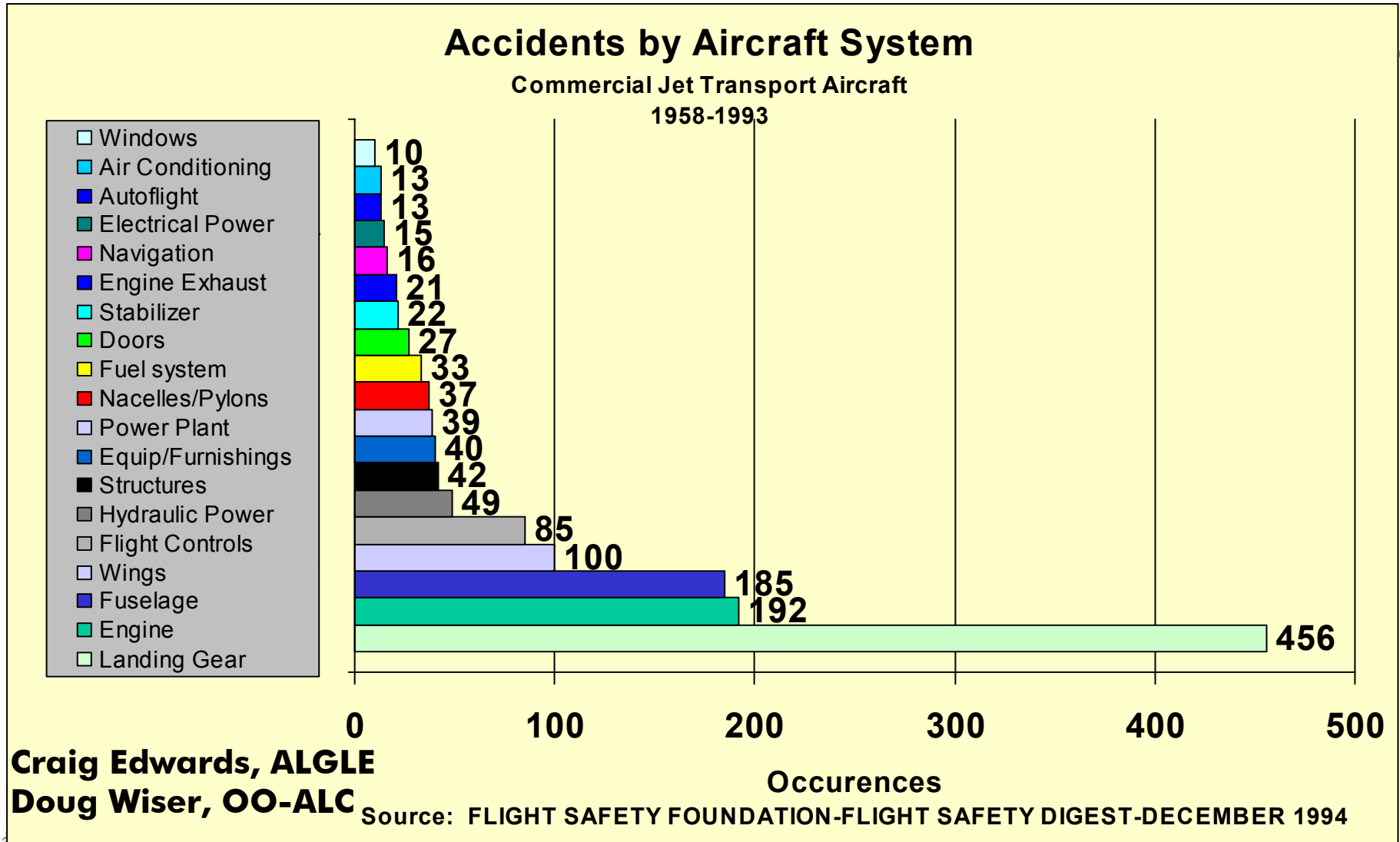
- **Less processing**
- **Less risk of embrittlement failure (by H or Cd)**

Competitive

- **Increasing user demand**
 - especially European markets (e.g. A380)

USAF LG

Why landing gear?



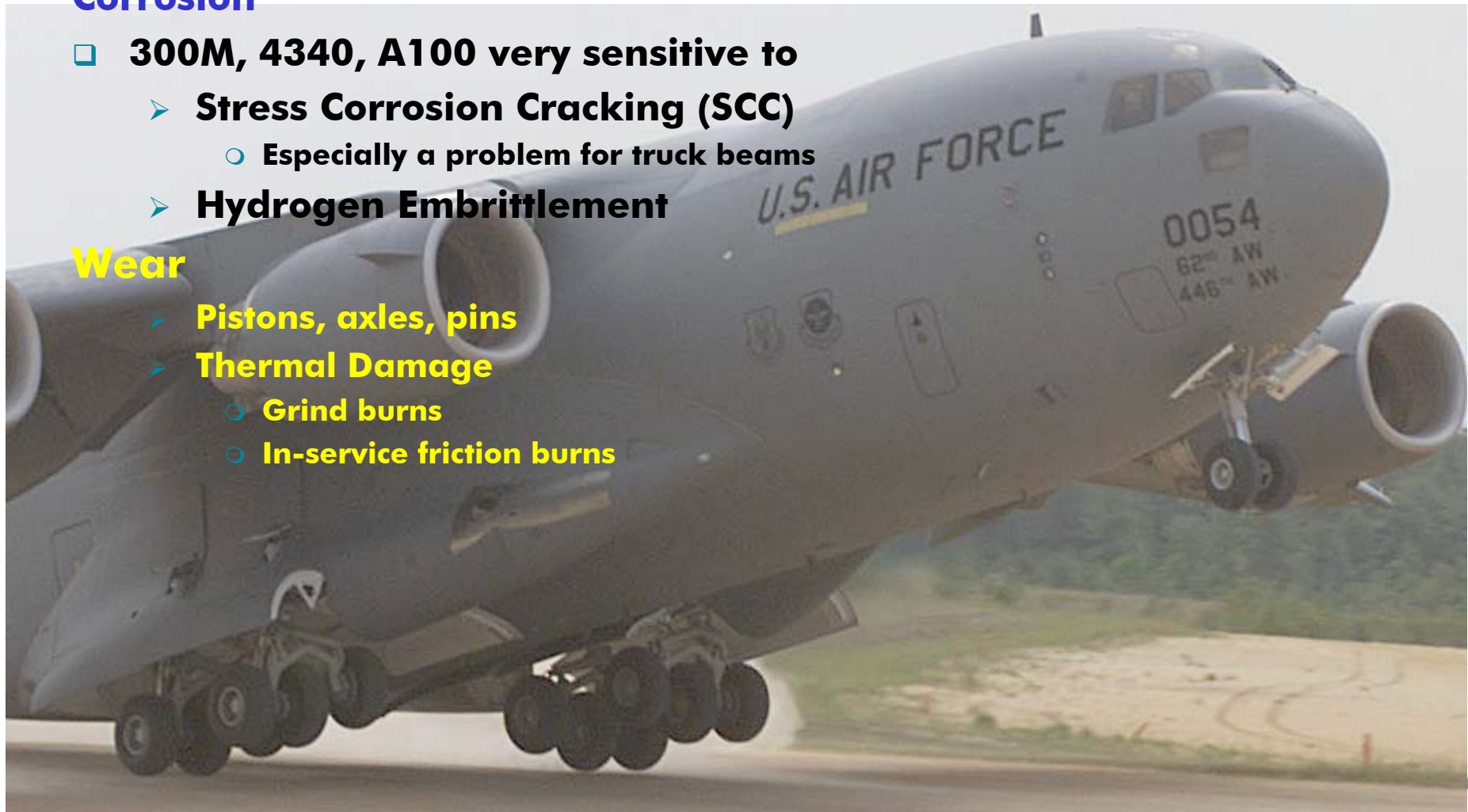
Landing gear issues

Corrosion

- ❑ **300M, 4340, A100 very sensitive to**
 - **Stress Corrosion Cracking (SCC)**
 - Especially a problem for truck beams
 - **Hydrogen Embrittlement**

Wear

- **Pistons, axles, pins**
- **Thermal Damage**
 - **Grind burns**
 - **In-service friction burns**



Barriers for Cd and Cr replacement

□ Cost

- Capital equipment
- Process costs
- **Validation costs**
 - process optimization
 - lab testing
 - rig and flight testing
- **Changes in drawings, Tech Orders, contracts, training**

Biggest cost by far

□ Risk

- **All change is risk**
- Cd and Cr have serious tech issues but we know where the mines are
- **Technical risk**
 - Replacing a single coating with several alternatives – logistics, cost
 - We don't know what we don't know
- **Political risk**
 - Changes are made only where decision-makers can balance **upside reward** against **downside risk**



The No-bull Prize

Environmental concern is
a driver for
considering change

but when the chips are down

acceptance is driven by
cost
risk
performance
reliability



Identifying the viable options

- ❑ **Keep up with technology and what people in industry are doing (including overseas)**
 - **Learn from the commercial sector**
 - **Commercial world tends to be ahead**
 - **Amazing what you find out when you talk to people!**
 - **Non-aviation markets often adopt earlier because of lower technical risk**
 - **Not necessarily lower commercial risk (cost)**
 - **Technology has to match, not just specs, but usage**
 - **Analysis requires strong technical background**

In competitive intelligence and market analysis we call interviewees “primary sources” and written data “secondary sources” – but need both

Checking out the options

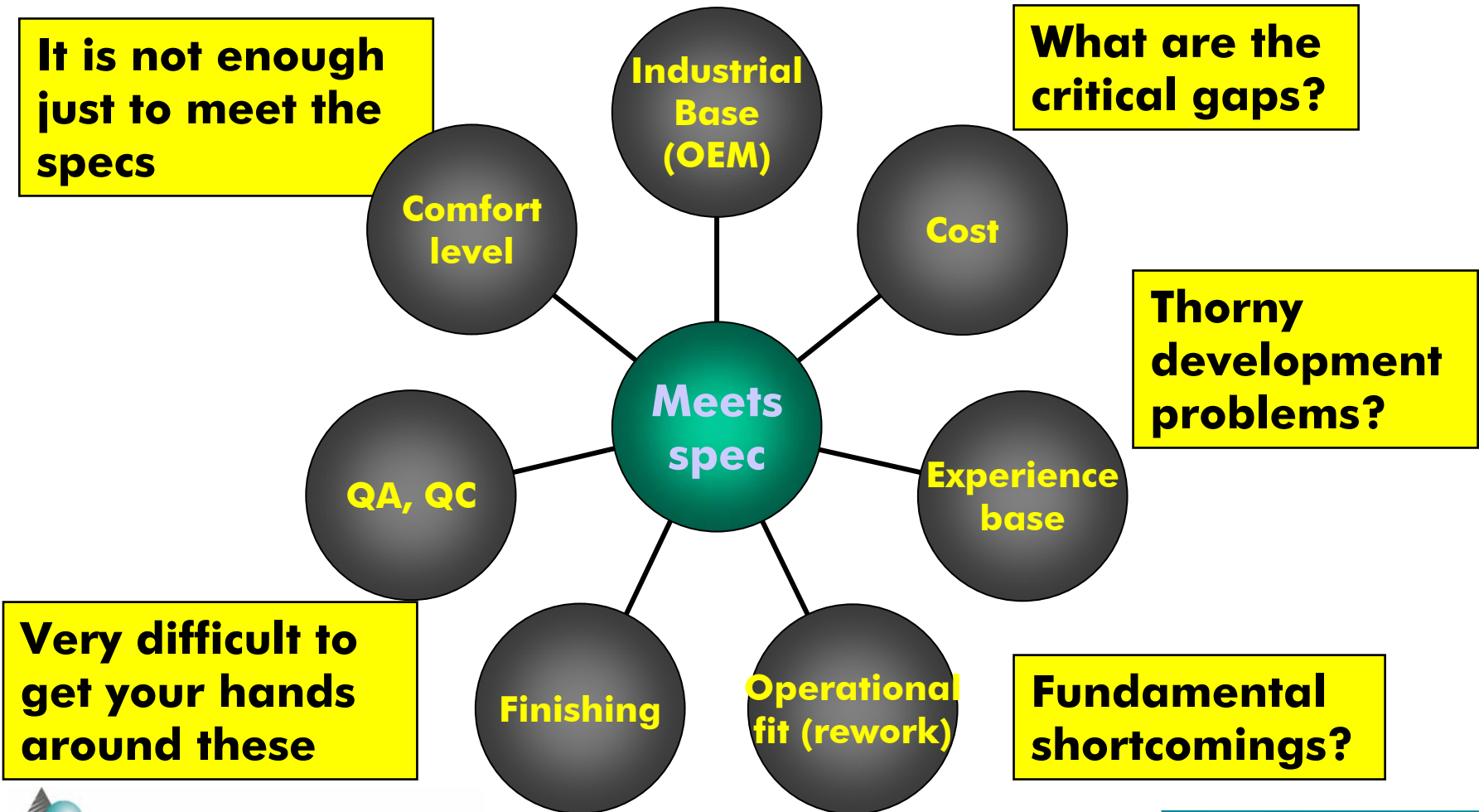
□ Paper evaluations a good start

- **Relatively inexpensive, cover a lot of ground**
- **Can consider a lot of the broad issues**
- **Requires breadth and depth of expertise**
- **No “own technology” or axes to grind**
- **Be willing to make politically incorrect calls**

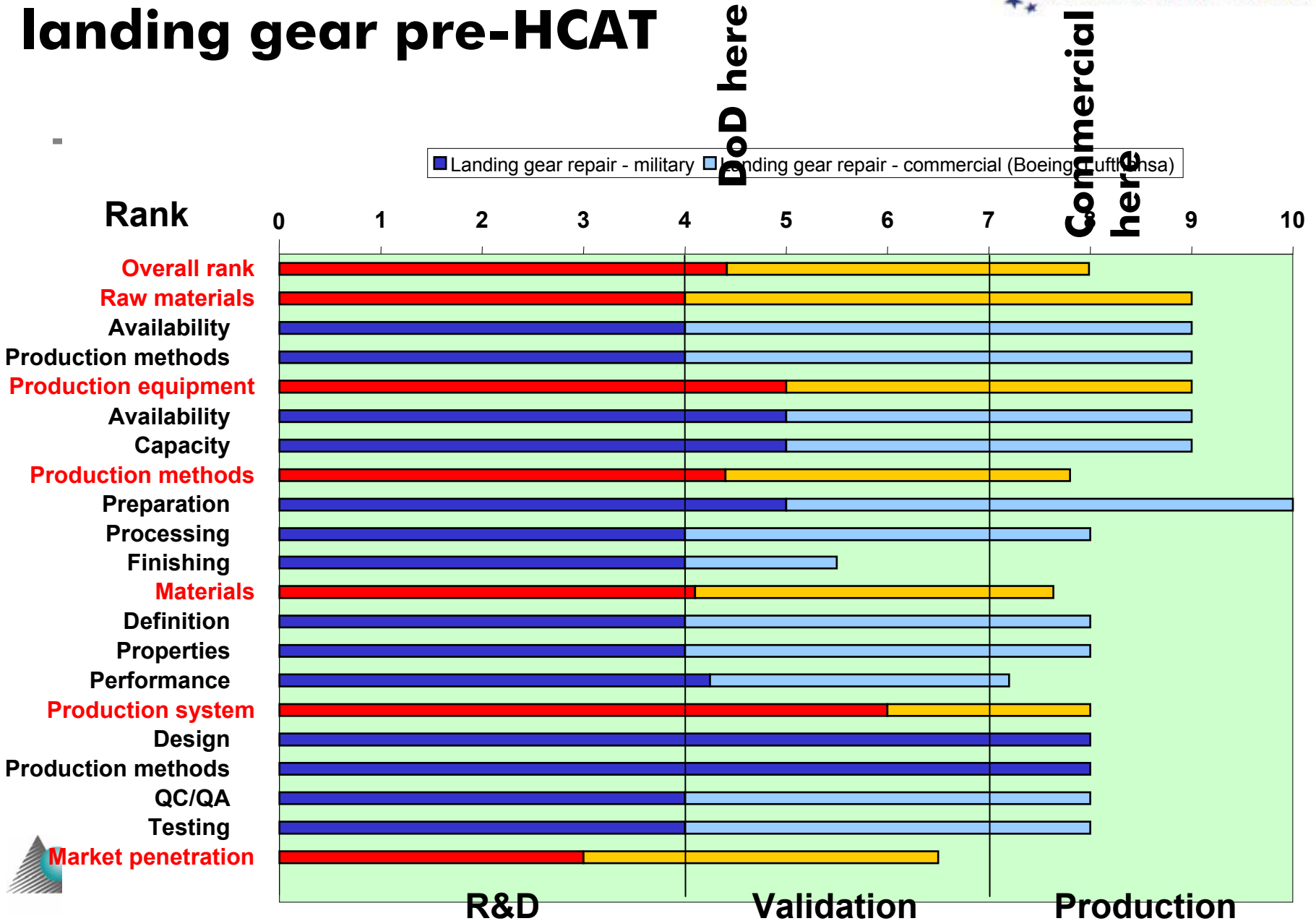
□ Relatively inexpensive lab evaluations

- **AFRL \$25k screening tests**
 - **Does the technology do what the vendor says it does?**
- **SERDP SEED**
 - **\$100k is a lot cheaper than years and millions!**
 - **Can try promising but off-the-wall ideas**

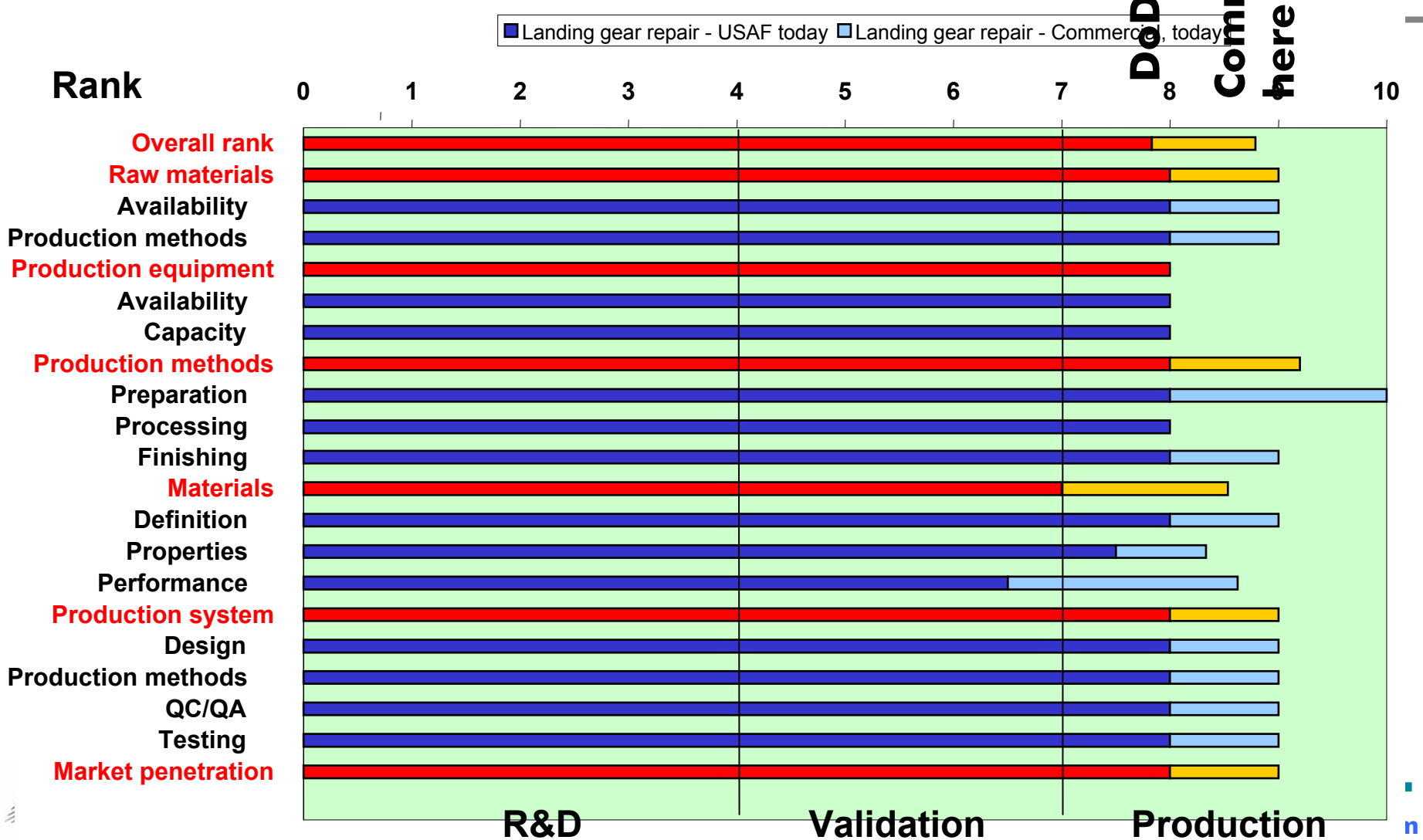
Meeting requirements



Technology Assessment Matrix – landing gear pre-HCAT



Technology Assessment Matrix – today



Technology identification examples

- **Stainless steel landing gear – Cd alternative**
 - **Computational methods “too good to be true”**
 - **SERDP SEED program**
 - Demonstrated viability in a few months
 - **SERDP development program**
 - SERDP Project of the Year Award
 - **ESTCP validation program**
 - Hill AFB project lead

- **Alternatives to ID Cr for landing gear, hydraulics**
 - **JSF IPT evaluation identified best options**
 - **Electro(less) alloy and composite plates**
 - **Co electrocomposites**
 - **Plasma spray**
 - **ESD**
 - **SERDP development, evaluation**
 - Included nanoplating
 - **AFRL evaluation of Ni-based plates**

But what does it really cost?

- ❑ **All kinds of cost calculations – wonderful (or lousy) ROI, short payback period, etc.**
- ❑ **Most take into account process and materials and environmental costs, but not the costs and savings that often make or break the deal**
 - + **Risk reduction, maintainability, field failure**
 - **Qualification, paperwork changes, rig testing**
 - **Why would anyone ever change? It's just a big cost!**

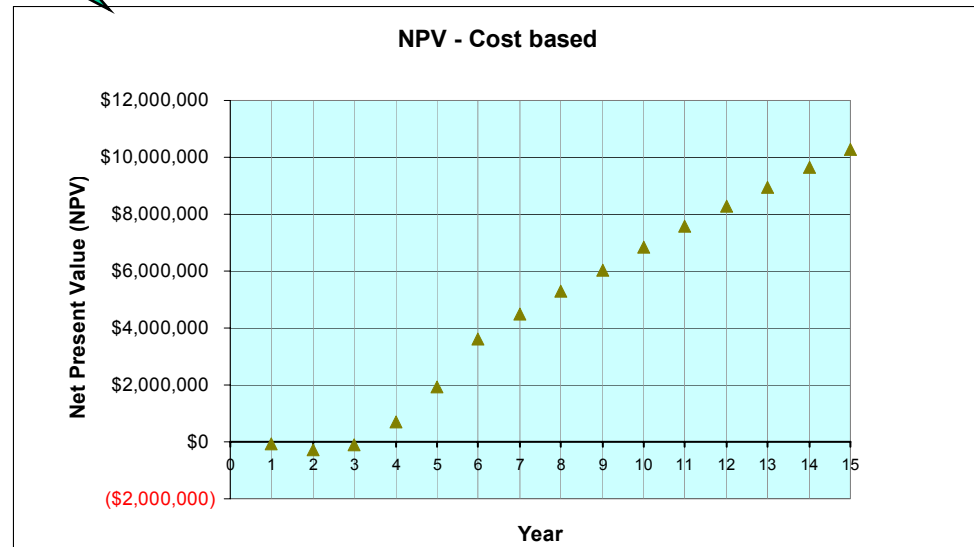
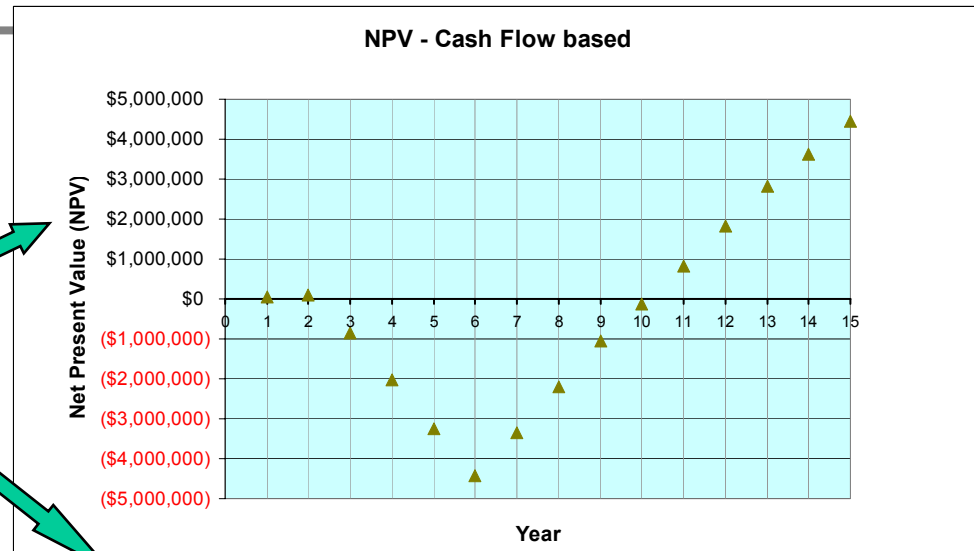
Cost/risk based decision tool

❑ SERDP Stainless Landing Gear

- Decision tool based on all costs
- Revenue-based for OEMs
- Cost-based for depots
- We don't know all the numbers accurately – need to account for uncertainty – also part of risk
- Graphical output

❑ Allows users to play with their own numbers

- Account for all the potential costs and revenues
- Play “What if” to make cost/risk decisions



Validation – Assembling the team

- ❑ **Identify **critical** stakeholders and experts at outset**
 - **Too many and you never get anything done**
 - **The wrong ones and you can't get buy-off in the end**
 - **Problem of rehashing as more join**
- ❑ **Small sub-teams with clear leadership responsible for defining and carrying out different parts of the work**
 - **In HCAT a different sub-team of stakeholders and experts handled each test**
 - **Exerts pressure to get the job done**
 - **Final buy-in from stakeholders**

Validation – Defining the test program

- ❑ **Not just what tests, but what do stakeholders need to know?**
 - **Can be difficult to get clear requirements**
 - **May not even be known until something does not meet one**
 - **In HCAT very difficult to get solid answer on stress levels**
 - **Testing much more extensive than you expect as engineers have to feel comfortable**
 - **Will something you don't know bite you?**
 - **Far more extensive testing than required for QA/QC**
- ❑ **Always compare with valid baseline**
 - **Cr and Cd aren't just Cr and Cd**
 - **Different performance for different locations**
 - **Difficulty of establishing baseline**

Expecting the unexpected

- ❑ **How to get solid answers but allow for flexibility to handle unexpected results?**
- ❑ **Coating integrity issue in HCAT**
 - **Coatings delaminate at high cyclic stress**
 - Admission/acceptance of the problem
 - Honest discussions among team members
 - Understanding extent of problem/degree of importance
 - Testing by various team members with different approaches
 - ◆ Fundamental science to understand issue
 - ◆ New test development
 - ◆ Process improvement to minimize problem
 - ◆ Two-way flow of information
 - **Correlation of modified process with prior results to minimize retesting**
 - **Determine fundamental limits of the technology/material**
 - Individual team member decisions on importance and applicability

Qualification

- ❑ **Does it really, really work?**
 - **Thorough and convincing data**
 - **Rig and flight test data – not just coupons**
- ❑ **How exactly do you do it?**
 - **Coating, finishing, stripping, QA/QC, fit with depot maintenance**
- ❑ **Requires specs and standards**
 - **AMS, OEM specs, etc.**
- ❑ **Do people care enough to spend the money?**

And then what? – Getting it used

❑ Champions

- Depot engineers who daily struggle with inadequacies of today's technology
- Naysayers are important for critical assessment
 - Division of resources between fast and slow adopters
 - Put resources to the most likely adopters
- **The best driver is seeing others successfully using it and saving money doing so. Lowers risk.**

❑ Do the easy stuff first

- No brainers, non-flight critical parts
- Landing gear axles and pins first
- Carrier-based aircraft last

❑ Expertise available to put it in place and offer assistance

- Installed base becomes its own expertise

HVOF Cr replacement today

❑ Commercial

- **A380**
- **B767-400**
- **Delta, other airlines**
- **>100 BAC point solutions**



❑ Military

- **6 USAF landing gear applications qualified**
- **Baselined for JSF CTOL**
- **HS Nozzle actuators F22**
- **Messier-Dowty CF-18 A/B MLG hexagon repair**
- **Parker hydraulics**



Cd replacement today

Cad replacement

❑ Commercial

- Little or none for aircraft
- Al-filled polymers for automotive fasteners

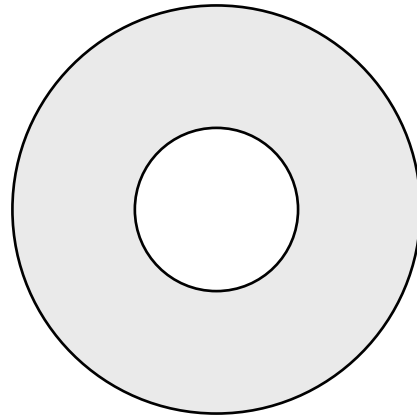
❑ Military

- IVD Aluminum, OEMs and depots
- SerMetel F-22
 - moderately successful
- Stainless fasteners P&W F119 GTE (F-22, F-35)





Materials Substitution for Pollution Prevention in Advanced Aircraft - Technology Exchange



BWI - Airport Marriot,
Baltimore MD
September 4, 5 2002

**A variety of
reports on Cr
and Cd
replacement
available at the
HCAT booth**



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