



Plasma spray coatings for IDs

HCAT Program Review
Park City, UT
July 2004

Report Documentation Page

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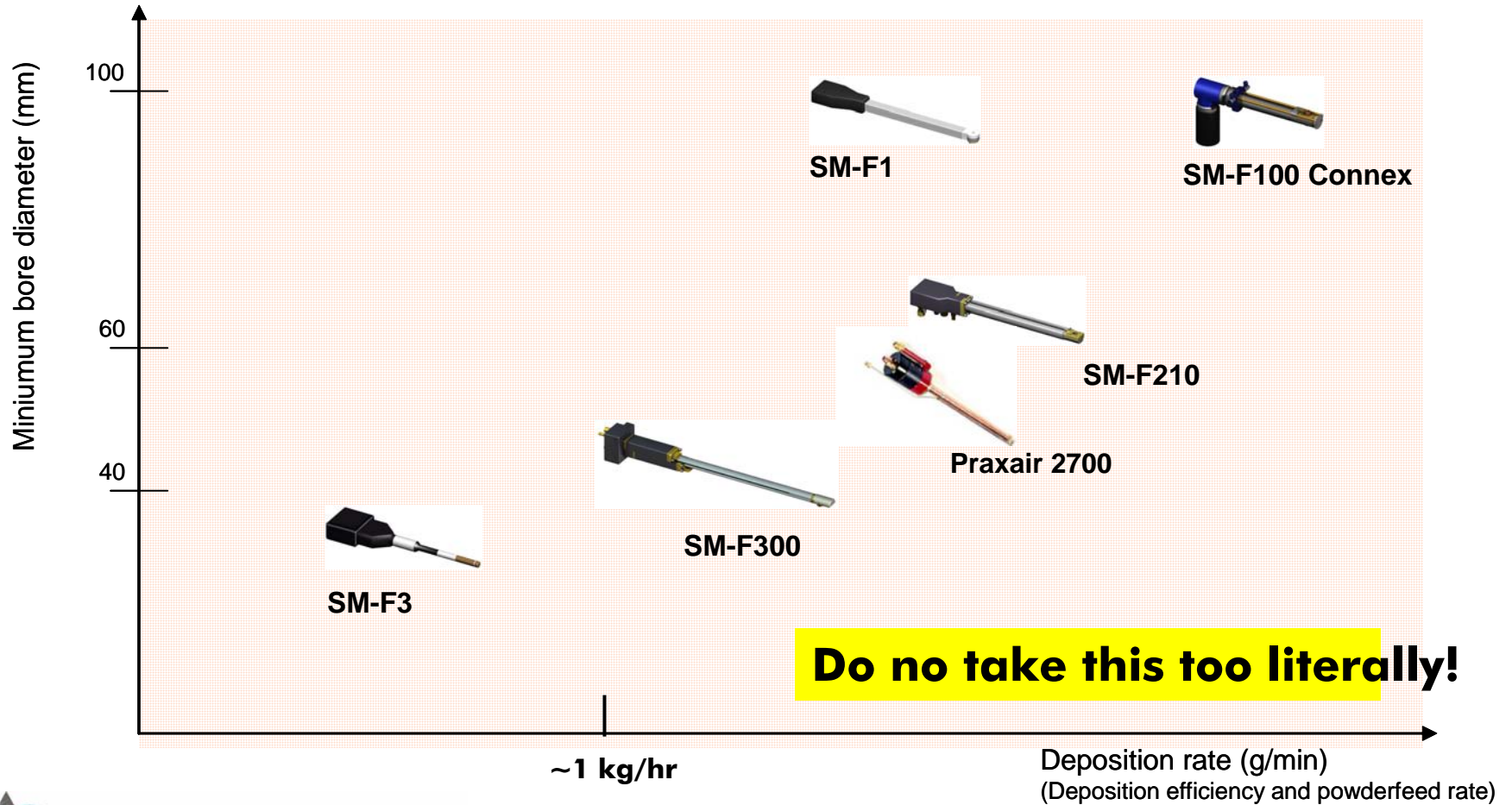
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Progress

- ❑ **Data on all materials complete (Praxair W-121 added)**
 - **Corrosion**
 - **Wear**
 - **Structure, hardness, microstructure**
 - **4-point bend testing done at NRC**
- ❑ **Spray visualization system developed at NRC**
- ❑ **Corrosion:**
 - **Potentiodynamic measurements found to be not useful as corrosion current only through Cr cracks to substrate, but all over thermal spray surface**
 - **Will run B117 as well**
 - **Specimens sprayed at Sulzer Metco**
 - **To be sprayed at Praxair in a week**
- ❑ **Sulzer to spray ID of demo part (F-18 LG outer cylinder) and 3" tube for cut-up**

ID guns and spray rates

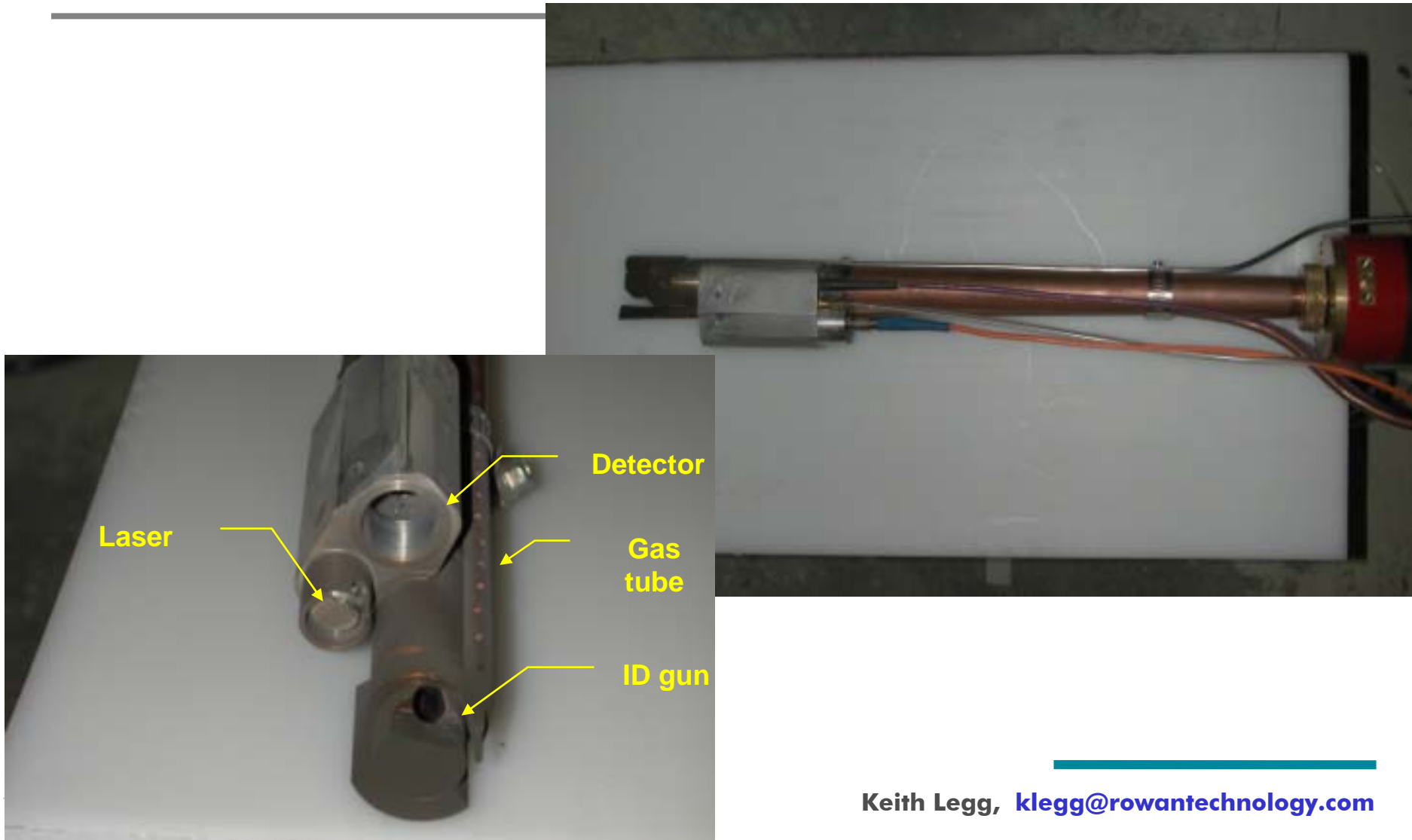


Plasma spray coatings optimized

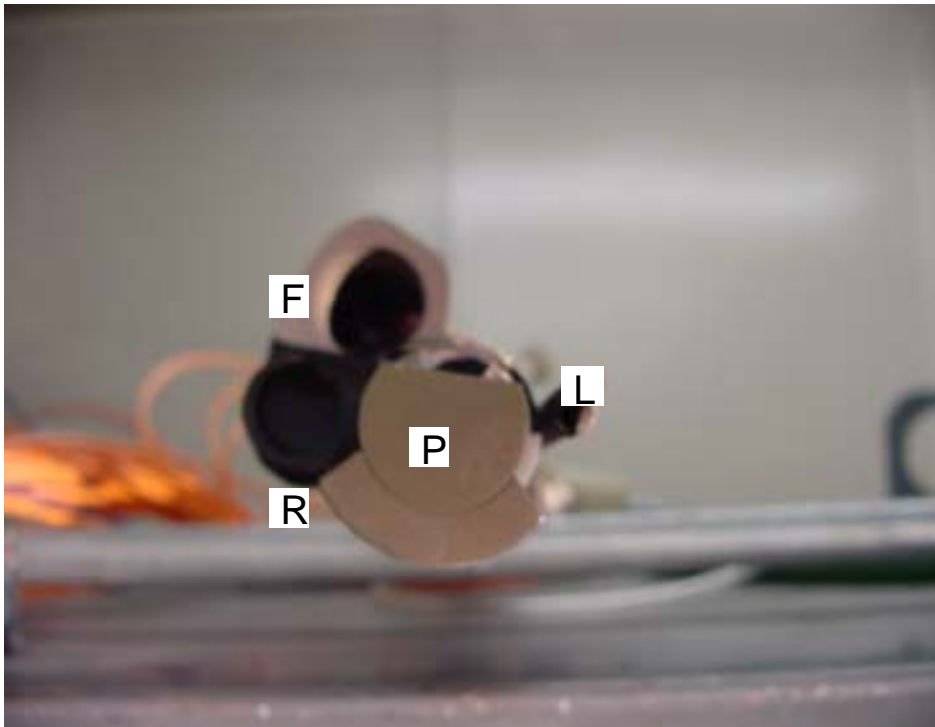
Powder	Chemistry	Comments
Diamalloy 2003 (Sulzer Metco)	WC-12Co	Fused and crushed. Contains WC and W₂C.
Diamalloy 2002 (Sulzer Metco)	55%(WC 12Co) 45%(66Ni 18Cr 7Fe 4Si 4B 1C)	~55/45 mixture of WC-Co in self fluxing binder
Ni-988 (Praxair)	50%(WC 12Co) 50%(66Ni 18Cr 7Fe 4Si 4B 1C)	50/50 mixture of WC-Co in self fluxing binder
Co-109-3, Tribaloy 400 (Praxair)	Co-28 Mo-8 Cr-2 Si	Fine cut powder
W-121 (Praxair)	WC-Cr₃C₂-NiCr	Precipitated

**Additional coatings tested by Sulzer Metco, but no advantage over existing coating
Hastelloy, NiCr, Cr₃C₂-NiCr, fine WC-Co**

Optical overspray monitoring



Configuration of the gun



- ❑ **F sensor head**
- ❑ **P is the plasma gun**
- ❑ **L refers to left-hand side**
- ❑ **R refers to right-hand side**

Type of Air Jets Used



Multiple

Spray direction (left, right)

Straight

The jets were installed on both sides of the plasma gun alternately for the measurements

Multiple nozzles



Left configuration

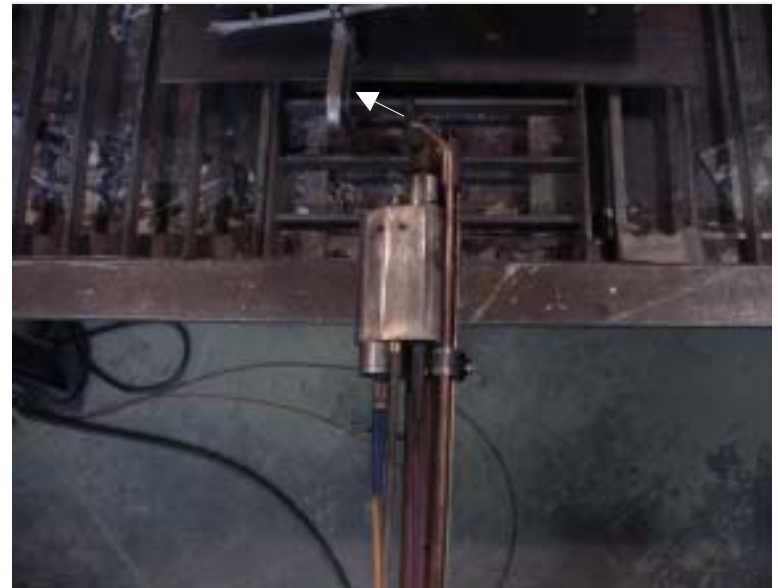


Right configuration

Left and right nozzles



Left configuration



Right configuration

Straight left and right

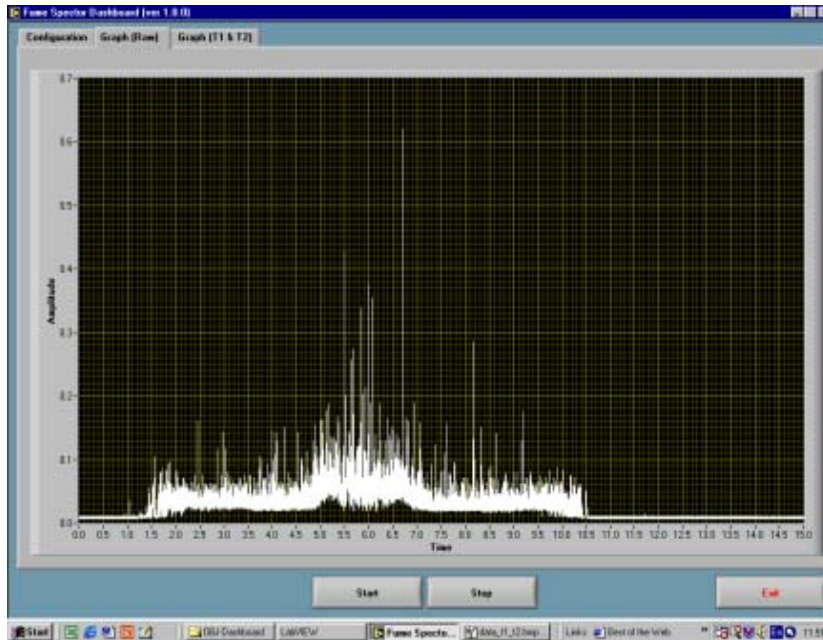


Left configuration

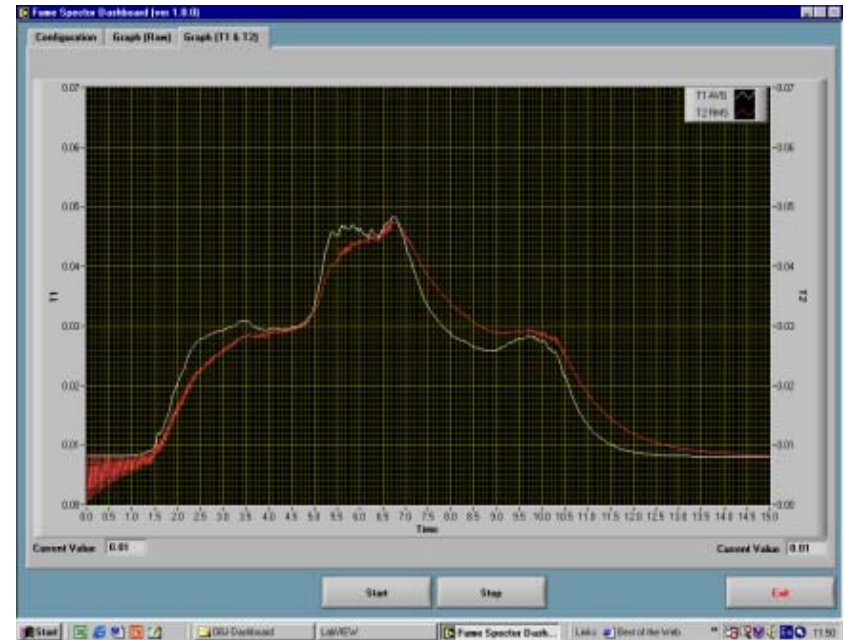


Right configuration

Fumespector Signal Processing



Raw Data



Treated Data

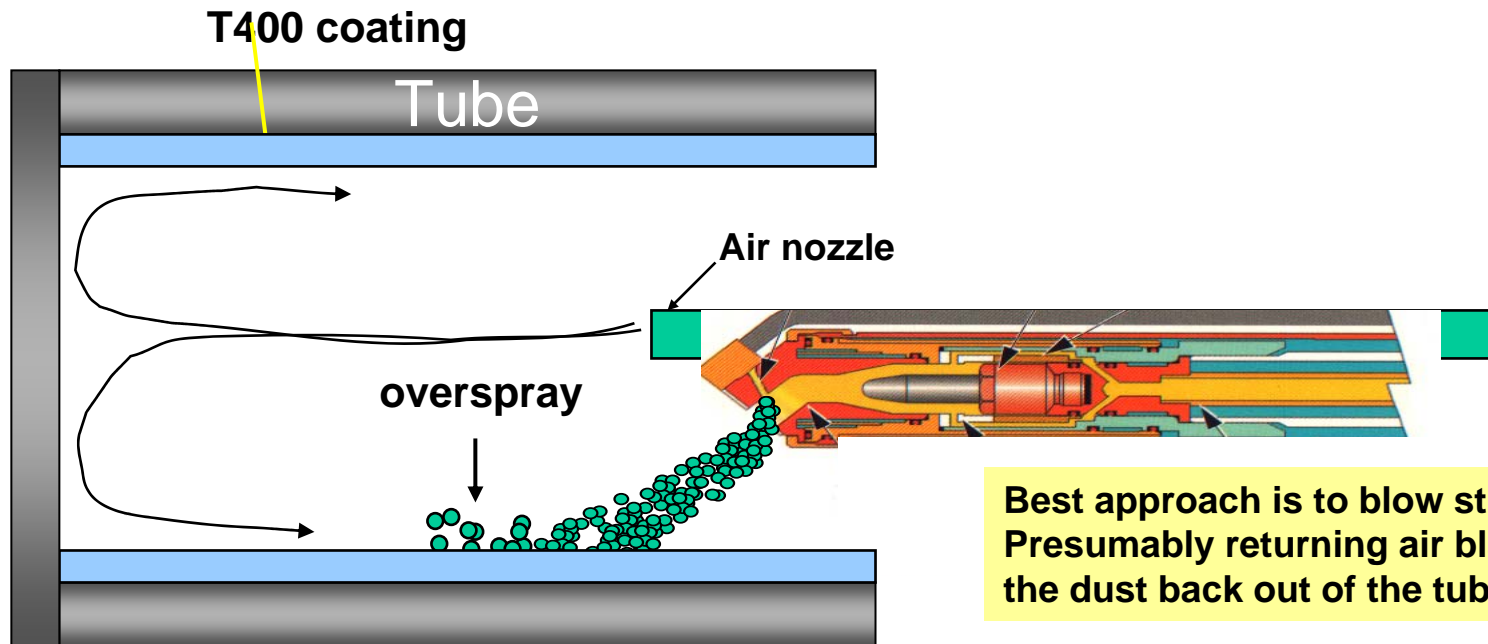
Signal strength as traverse in, then out again in a closed-end tube

Signals from the Detector

Configuration	Mean signal (mV)	RMS (mV)
1 multiple right	1781	22.3
2 multiple left	2098	26.2
3 spray direction right	2980	37.3
4 spray direction left	3013	37.7
5 straight right	2648	33.1
6 straight left	1729	21.6

The highest overspray was with the nozzle pointing at the wall, while the lowest was from the straight left and multiple right.

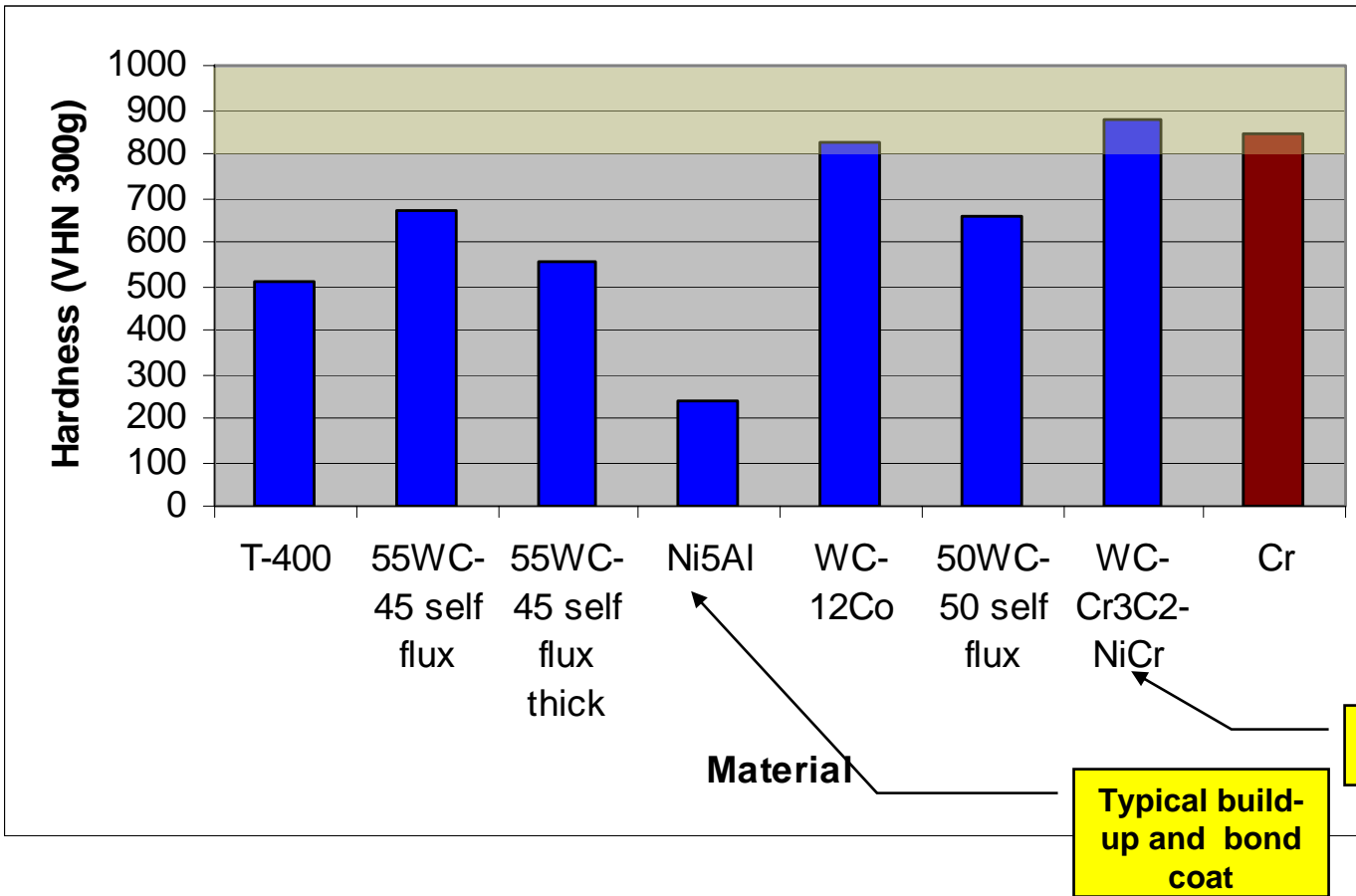
Overspray dust control





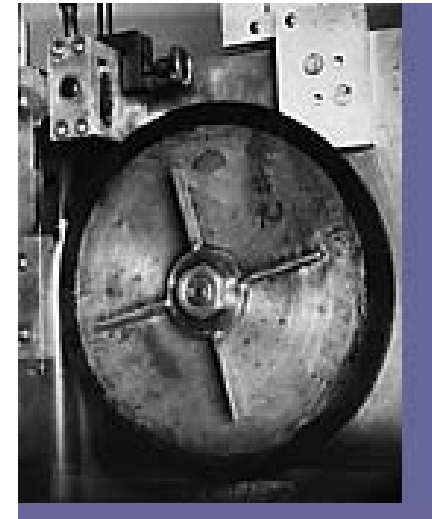
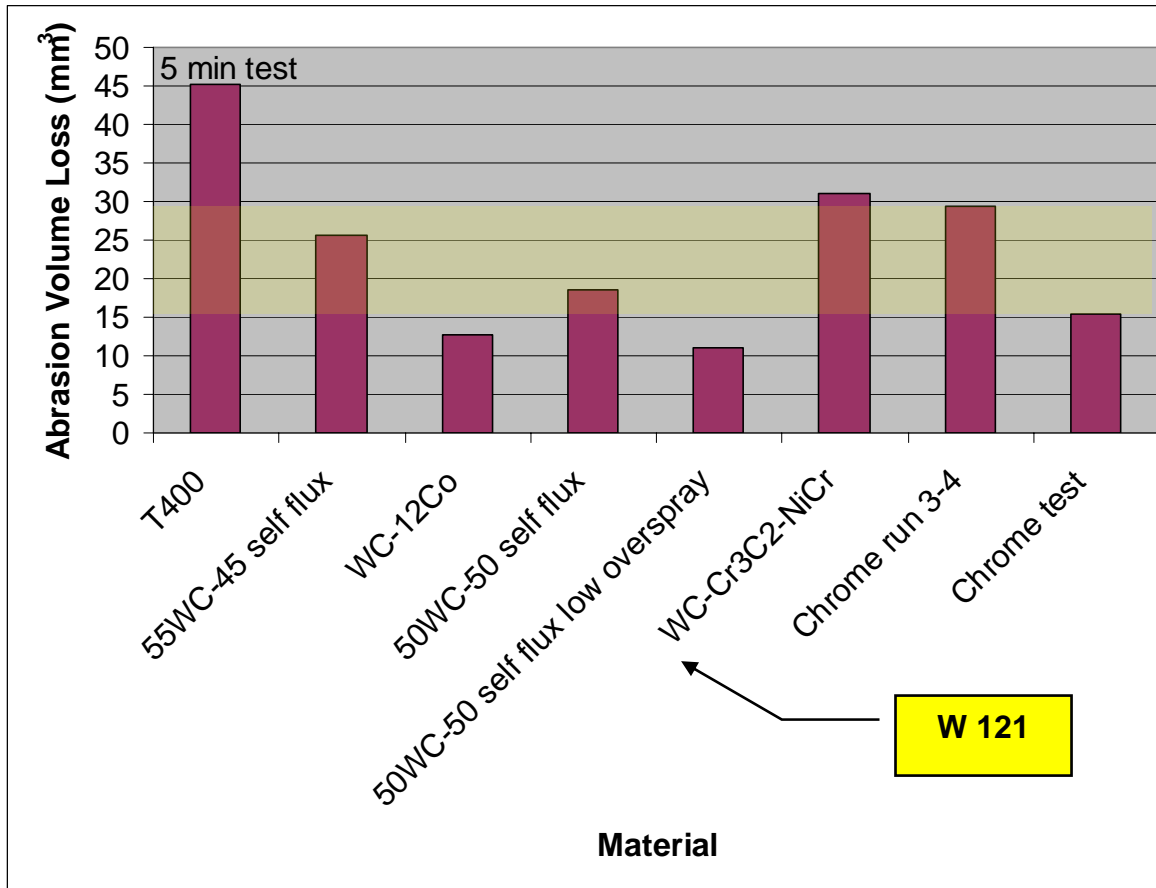
Performance

Hardness



Note: Only WC-12Co and WC-Cr₃C₂-NiCr are as hard as EHC

Abrasion resistance – ASTM G-65



Rubber wheel + dray sand

WC-Cr3C2-NiCr not very good

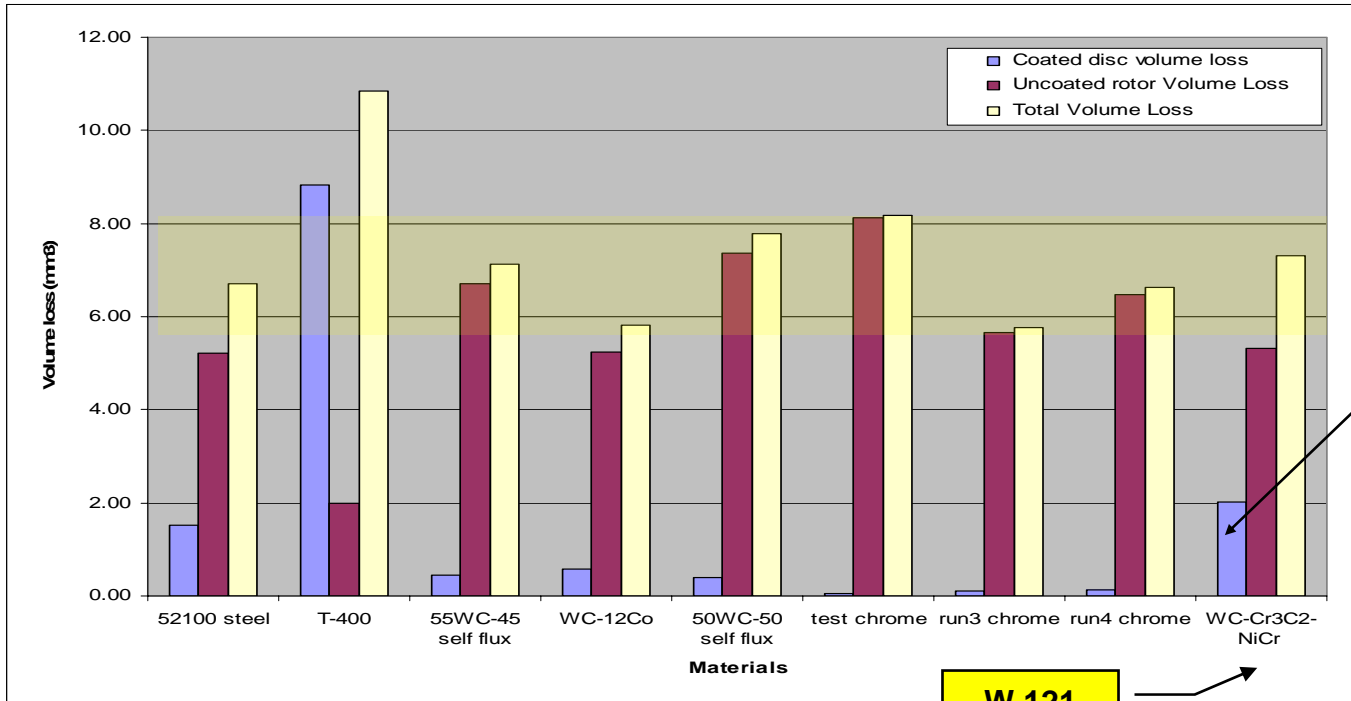
With best overspray removal, self-fluxing material is as good as WC-12Co

Test: Rubber wheel, dry sand abrasion

Test relevance: Debris in hydraulic fluid

Note: Abrasion resistance increases with hardness, but depends also on material.

Sliding Wear

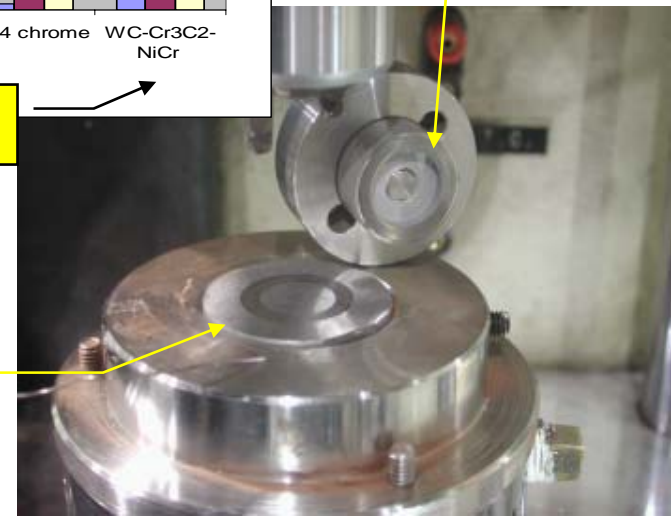


WC-Cr3C2-NiCr not very good for coating wear

Washer

W 121

Coated disc



- Dry sliding, 5200 steel rotor
- What is most important is total wear
- All coatings show more coating wear than EHC, although WC coatings are similar
- Only Tribaloy shows significantly more total wear than EHC, primarily from coating wear

Conclusion from data so far

- ❑ **In general plasma spray works well for ID >2.75" most guns (1.6"ID for Sulzer F300 gun)**
 - **High deposition rate**
 - **Quality similar to OD coatings when properly optimized and flushed**
- ❑ **Technical properties generally acceptable**
 - **Abrasive wear better than EHC, but not**
 - **Longer repair cycle (lower LCC, less pollution)**
 - **Pin on disc wear not as good**
 - **Not a good measure of actual service performance**
 - **Corrosion current worse than EHC**
 - **Different mechanism, in common with other thermal spray**
 - **Probably need sealer for corrosion and high pressure leak-by**
 - **B117 testing to be done**
- ❑ **Producibility**
 - **Good, especially for shops already using HVOF for OD chrome replacement**



Implementation Assessment and Cost Benefit Analysis

Methodology

- We are doing an **Implementation Assessment** rather than a simple CBA because it tells us much more
- Using **C-MAT** cost model developed under **SERDP Stainless Steel Landing Gear** program



Implementation Assessment

Replacement of Internal Diameter Hard Chrome with Plasma Spray Coatings at NADEP Jacksonville

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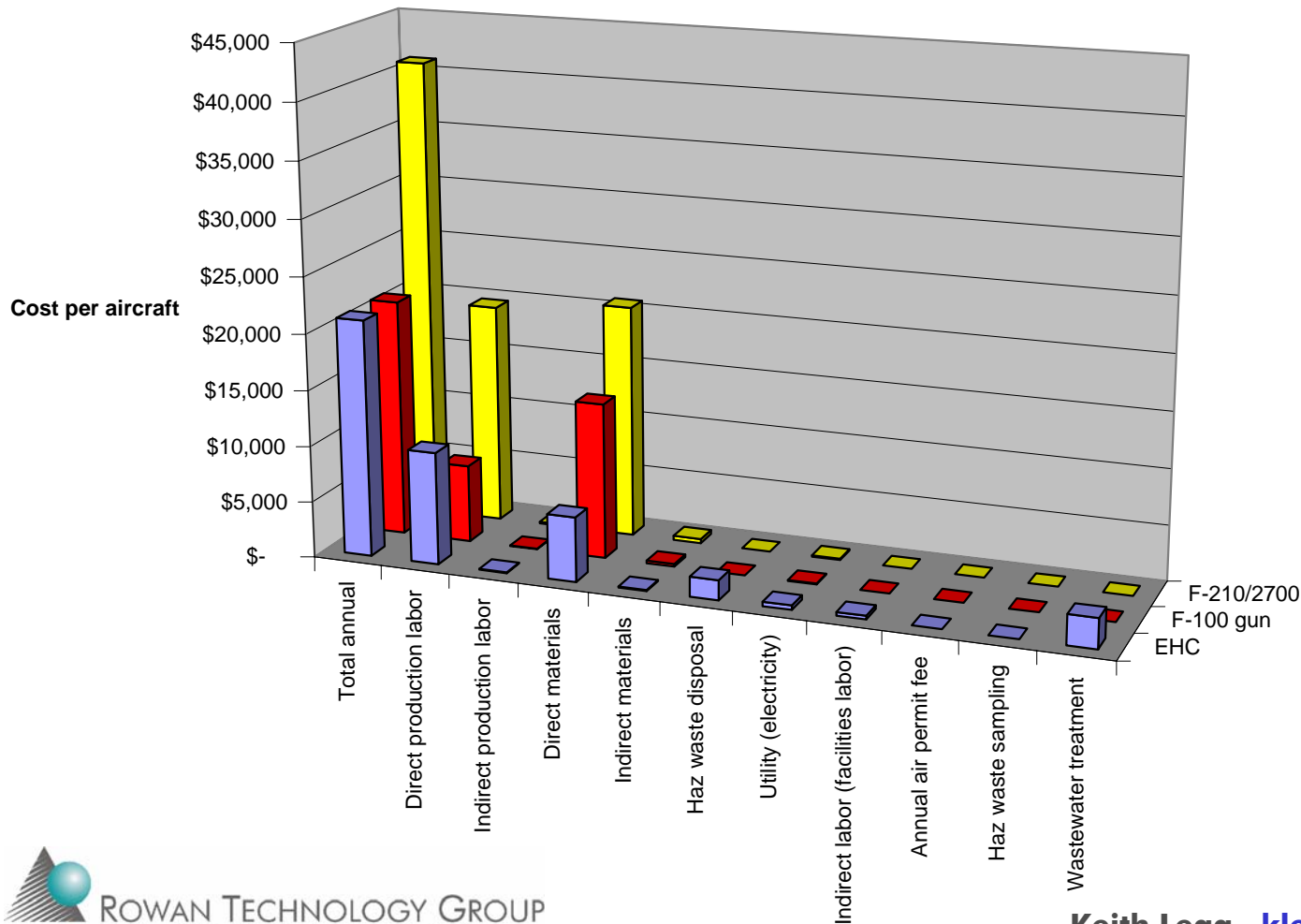
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Comparison of EHC vs APS process cost



Plasma spray with large ID gun is essentially same cost as EHC, but small gun is twice as high (lower rate, longer time).

EHC cost data from F-35 analysis, with APS cost data from HCAT and ID team

Use a big gun!

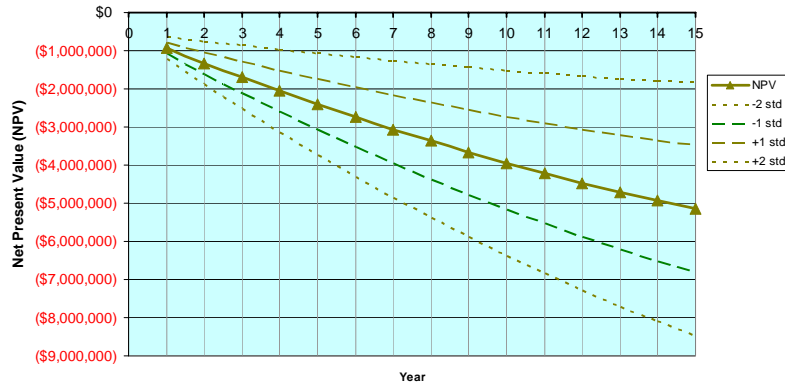
Is there a cost driver for replacement?

- ❑ **If the process cost is the same or higher, when you add in the capital cost and the qualification and adoption cost, it cannot be cost-effective**
- ❑ **But there are two other cost issues**
 - **Performance**
 - **Abrasive wear rate looks as though it could be 1/2 EHC**
 - ◆ **Will need service data to know if same or better**
 - **Double overhaul cycle**
 - **New OSHA PEL**
 - **Probable PEL of 1 $\mu\text{gm m}^{-3}$ (as against today's 100 $\mu\text{gm m}^{-3}$)**
 - **Navy/Industry task force estimated high costs at this level**
 - **Analysis of their evaluation shows EHC cost **doubles****
 - **Raises the risk of sticking with EHC**

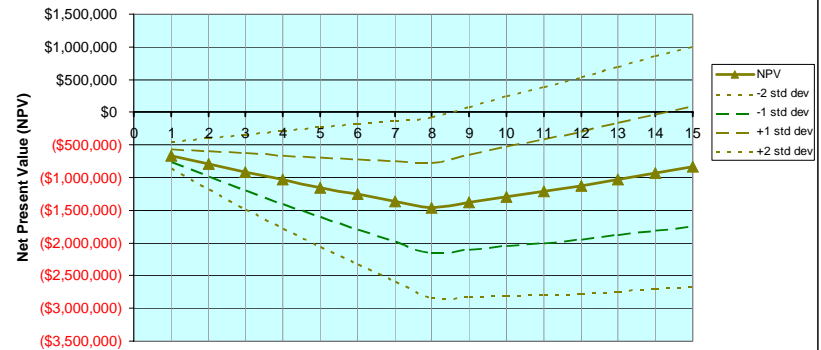
Some simple calculations

F210 gun

NPV - Cost based

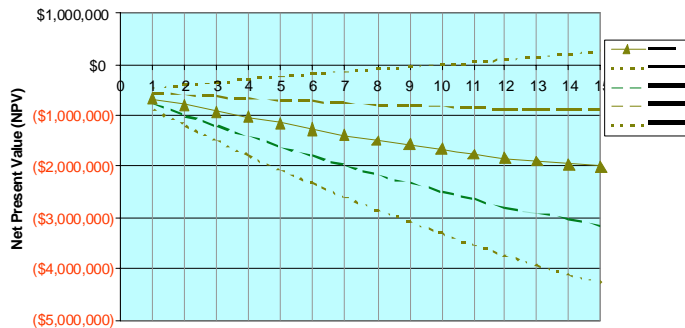


F-100 gun lower wear rate



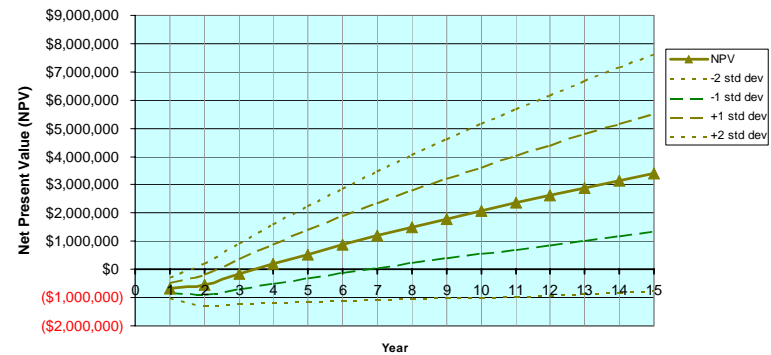
F-100 gun

NPV - Cost based

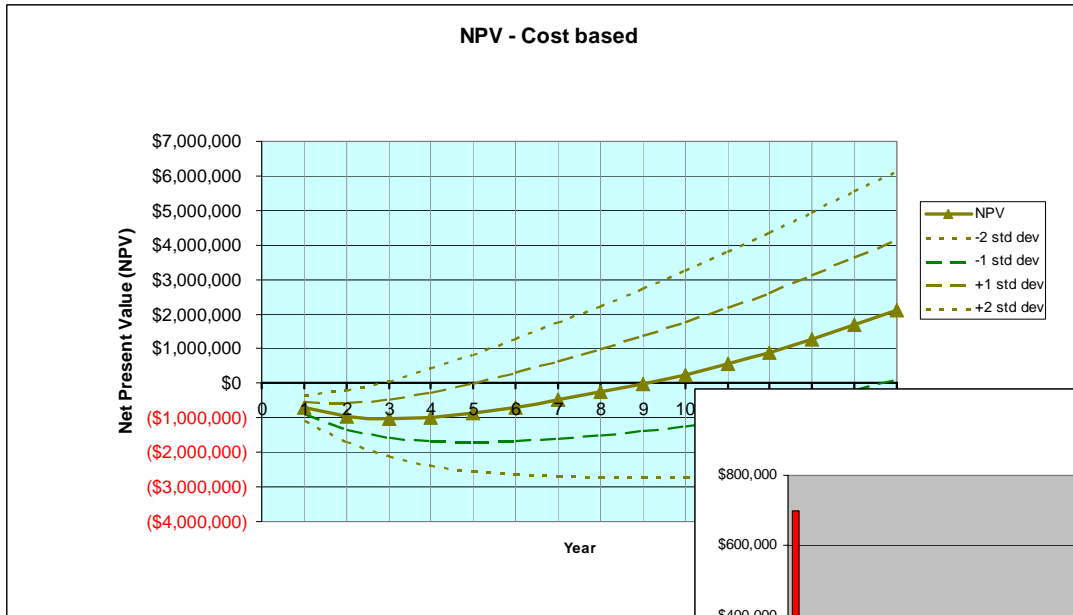


F-100 gun lower PEL

ost based



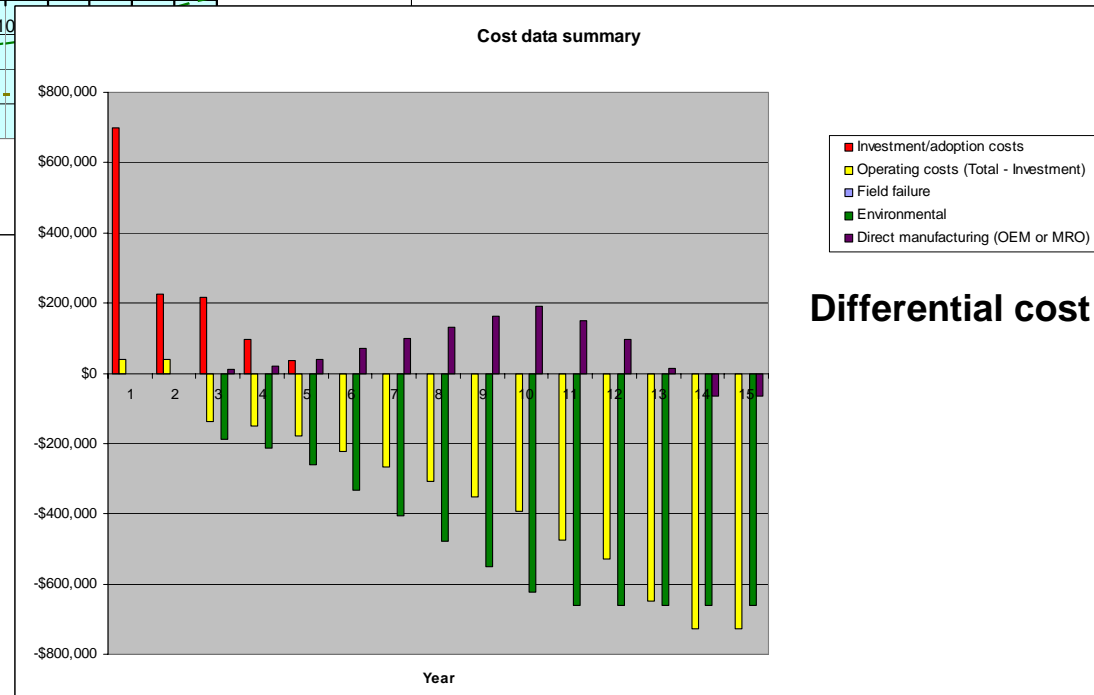
Realistic calculations



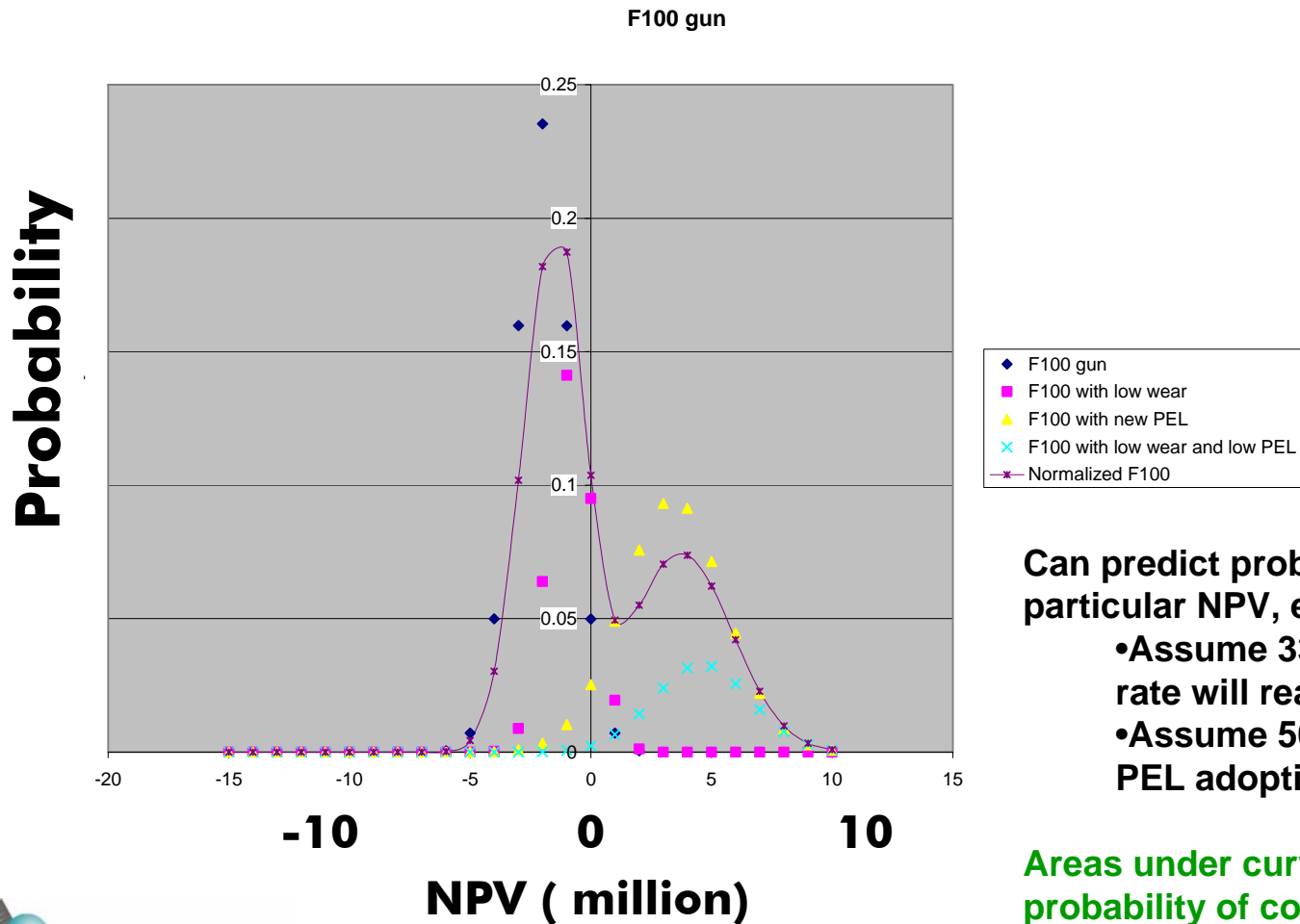
	-2 sigma	Value	+2 sigma
NPV	(\$1,920,239)	\$2,105,661	\$6,131,562
IRR	-6%	14%	31%
ROI	25%	47%	69%
Payback period	5.1	8.3	11.2

Assumes

1. the coating is more wear resistant
2. the PEL is adopted and costs as much as expected



So, what is the likelihood it will really be cost-effective?



Can predict probability of a particular NPV, e.g.

- Assume 33% chance wear rate will really be $\frac{1}{2}$
- Assume 50% chance of PEL adoption and cost

Areas under curves – 50% probability of coming out ahead

Reducing the financial risk

- ❑ **Use large ID gun to make as efficient as possible**
 - **Will coat most items of importance**
- ❑ **Keep on top of OSHA to see where PEL headed**
- ❑ **Calculate real potential cost of lower PEL at any depot wanting to adopt plasma spray**
 - **Remember cost based on overall Navy costs, which could be way off (high or low) for specific location**
- ❑ **Get some early rig test data of true wear rate on components in rig test or service**
 - **Is there an improvement in wear in service?**

But is it worth doing anyway?

- ❑ **The real reason JAX wants to use ID plasma spray or nCo-P is **turnaround time****
- ❑ **All depots have high war-footing workloads**
- ❑ **Any item in the depot is not available to the fleet**
- ❑ **Faster turntime reduces work-in-process**
 - **Faster return to action**
 - **Reduces total inventory of spares needed by the fleet (Col Diehl, Tinker AFB)**
 - **Improves both war-readiness and logistics**
- ❑ **Faster depot processing also increases total depot workload that can be processed**
 - **Higher depot cash flow**
 - **Better finances to implement improvements**



Thus faster turnaround is critical to readiness and reduces fleet costs, even though it makes no direct financial impact on that specific component or process being assessed

Cost impact should be considered on a broader basis since readiness impact is now critically important

Where to on environmental cost analysis?

- **New ESTCP-funded effort with OC-ALC and Pratt & Whitney to create a simplified cost model for strategic decision making**
 - **Idea is to make a simple model that engineers can use to show materials change is **sound business policy**, not just ESOH mandate**
 - **It will include all the true costs **to DoD** of using hazmats**
 - **It will have default values for average costs and will link cost reduction with hazmat reductions through P&W's Hazmat Index for quick assessment of potential costs, benefits and hazmat reduction**
 - **Prioritization of environmental projects**
 - **Strategic decision making**

What will this new tool do?

- ❑ **Give a global estimate of average costs that captures the **true costs** of using hazmats (and therefore the true benefits of using clean technologies)**
 - **Cost to DoD over the life cycle, not cost to the plating shop**
 - **Provide comparable costs for clean technologies**
- ❑ **Provide a DoD-recognized approach with standard “default” costs so people can compute costs and benefits in a consistent manner**
 - **Initial estimate of costs since only one depot – to be improved and refined with additional depots later**