Test Cell Instrumentation Challenges Then and Now: AVT-126 to AVT-306

Keynote to
AVT-306 Specialist Meeting
Athens, Greece

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Scope

- History of Gas Turbine Instrumentation development under AVT
- Intent of each activity and takeaways
- Government, Industrial and Academic participation – widening the community
- Challenges
- Opportunities
- What next …?

Gas Turbine Instrumentation History under NATO AVT

AVT-126 AVT-128 (Technical Reports)	AVT-180 (Technical Report)	AVT-229 (Symposium)	ET-163 AVT-306 (Specialist Mtg)
2005 - 2010	2010 - 2014	2013 - 2015	2016 - 2018
AVT-126 – "Improving Engine Reliability" AVT-128 – "More Intelligent Gas Turbine Engines"	"Gas Turbine Engine Test Cell Instrumentation"	"Test Cell and Controls Instrumentation and EHM Technologies for Military Air, Land and Sea Turbine Engines" (…and breathe…!)	"Transitioning Gas Turbine Instrumentation from Test Cells to On-Vehicle Applications"

Continued involvement

- “the predictable, and often unwanted, return of a disreputable or prodigal person after some absence, or (more generally) to the continual recurrence of someone or something.”*

* English Oxford Dictionary

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• Identified sensor and actuator needs • Education of future engineers • Identified need for robust Test Cells required to validate sensors • Reliability analysis best placed in Test Cell • Best practice & SoA processes & procedures with NATO Partners • Inform OEMs of engine usage	• Activity strongly linked with industry best practice • Results exploited by NATO nations plus internationally (TTCP/US/UK PAs) • Cross-fertilization of data analysis methodologies and sensors available across NATO • Aligned sensor development overview jointly with PIWG/EVI-GTI Lab Gap Matrix	• Communicating Best Practice through Industry & NATO • Advertising cutting edge sensors for accurate data collection • Encourage further workshops to develop routes for transition of sensor technologies e.g. EHM	• Identifying near term sensors for transition • Maturing and ruggedizing sensors for on-platform applications • Build a team of NATO partners* intent on advancing near-term sensors onto platforms

**plus AUS, FIN, SWE, UKR*

PIWG & EVI-GTI

EVI-GTI

- 2012 – Florence, Italy
- 2014 – New Jersey, USA
- 2016 – Berlin, Germany
- 2018 – Jupiter, Florida USA

EVI-GTI is a membership organisation for the Gas Turbine Instrumentation Community. Created in response to a need for a focal point and greater coherence in the sector.

EVI-GTI, **now part of IET**, meets during the Gas Turbine Instrumentation (GTI) conferences to include:

- Manufacturers of gas turbine engines and turbo systems
- Instrumentation supply chain companies
- Research institutes and universities
- Users of industrial gas turbines

IET The Institution of Engineering and Technology

http://piwg.org/matrix.html

The Lab Gap Matrix

- Measured quantities on one axis mapped against engine location / working environment on the other axis
- Measurement types structured
  - Each area highlighted green, yellow or red depending on level of maturity or availability

The Lab Gap Matrix

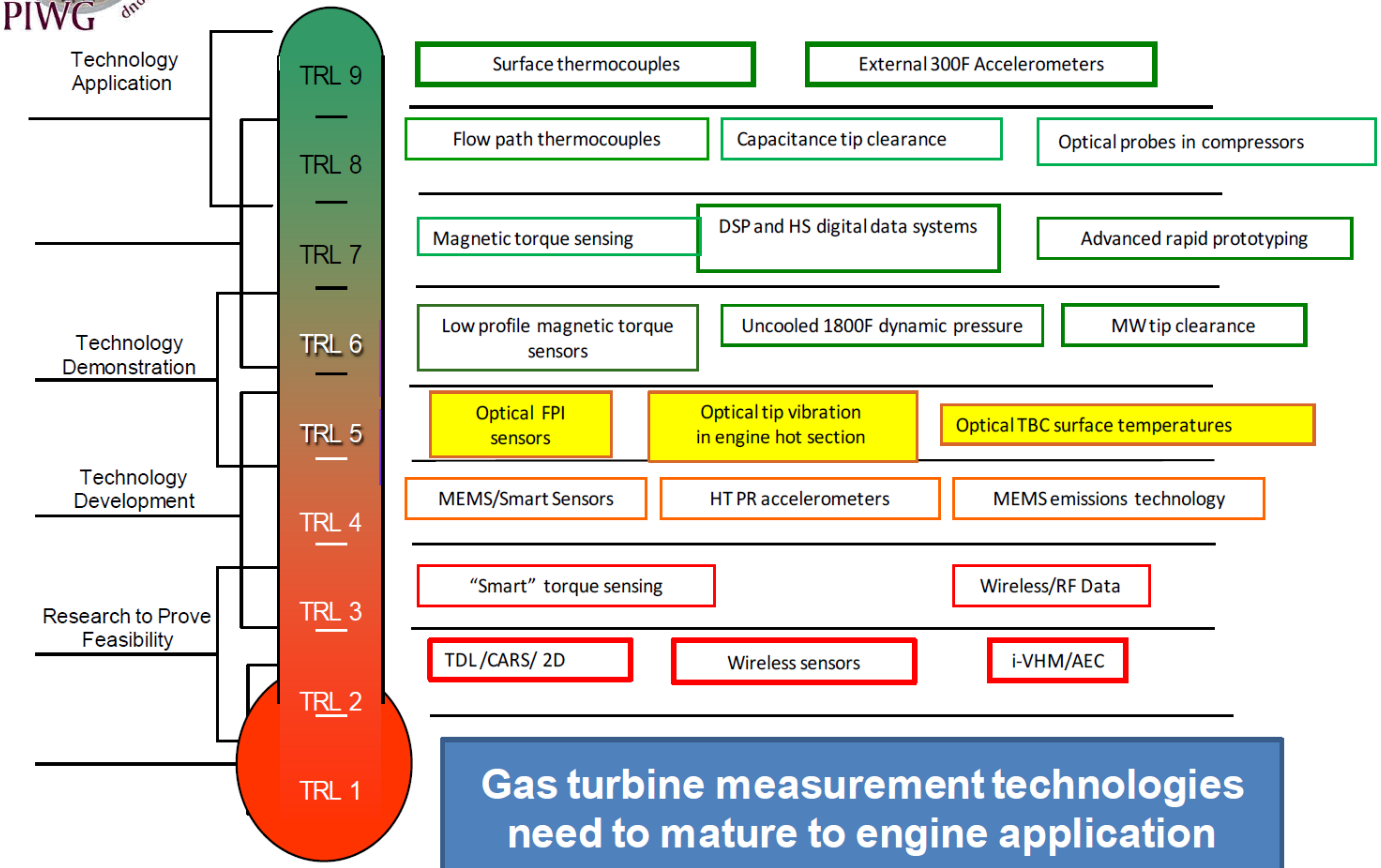
Rotating Structures
EVI-GTI- PIWG Joint Lab Gap Matrix
19-Nov-10

EVI-GTI

PIWG

Measurand/Measurement	Externals and shafts	Intake, Compressor (Front) and Fan	Compressor (rear)	Combustion system	HP Turbine	LP Turbine	Exhaust
Pressure (MKS)	1 bar	1-10 bar	10-45 bar	<45 bar	30-45 bar	1-20 bar	1 bar
Pressure (Eng)	15psi	15-150psi	150psi-650psi	650psi	370psi-650psi	15psi-300psi	15psi
Temperature (MKS)	-40 to 300C	-40 to 300C	700C+	700C-2400C	1000C-1800C	700C-1000C	700C+
Temperature (Eng)	-40 to 570F	-40 to 570F	1300F	1300F-4200F	1800F-3300F	1300F-1800F	1300F
TRL assessments = Red 1-4, Yellow 5-6, Green 7-9							
1. Boundary layer/heat transfer	EU US	EU US	EU US	EU US	EU US	EU US	EU US
Overview of gaps							
2.Component Temperature							
Overview of gaps							
2a. Surface Temperature: Metals							
2b. Surface Temperature on TBC							
3 Fatigue and Vibration							
Overview of gaps							
3a. Stress and Strain							
3b. Tip Timing NSMS/BTT/LP							
Enabling Technology: Signal transfer							
Enabling Technologies: Wiring and interconnects							

Lab Gap Matrix Measurement Technologies



Taken from AVT-RTG-180 Ch 2.4.2

Collaboration

What collaboration can also do…

Post-EVI-GTI/PIWG Workshop: AVT-ET-163 - Transitioning Gas Turbine Instrumentation from Test Cells to On-Vehicle Applications (GOTChA Chart)

EHM Higher Aim: To improve safety, allow better fleet management & platform availability & reduce cost of supportability

Goal	PROVIDE TEST CELL DERIVED TECHNOLOGIES TO SUPPORT THE HIGHER AIM					
Objectives DEVELOP	Revisit TCI – integrated roadmap with EHM	Define System Requirements – Onboard* & Off-board*		Make best use of existing technology		Prioritization of operational drivers
Technical Challenges OVERCOME	*Integration*	*Fault mode understanding & impact on system*	Maturing TCI to TRL6.	*Ruggedizing EHM System*	*Understand true capability of existing technology*	*Certifying Transitioned Technology*
Approach PLAN	Integrated roadmap with EHM	Requirements definition	Plan to define TRL criteria specifically for EHM	Define sensor specifications		Validation standards

* Including Actionable Condition Indicators

The Challenges

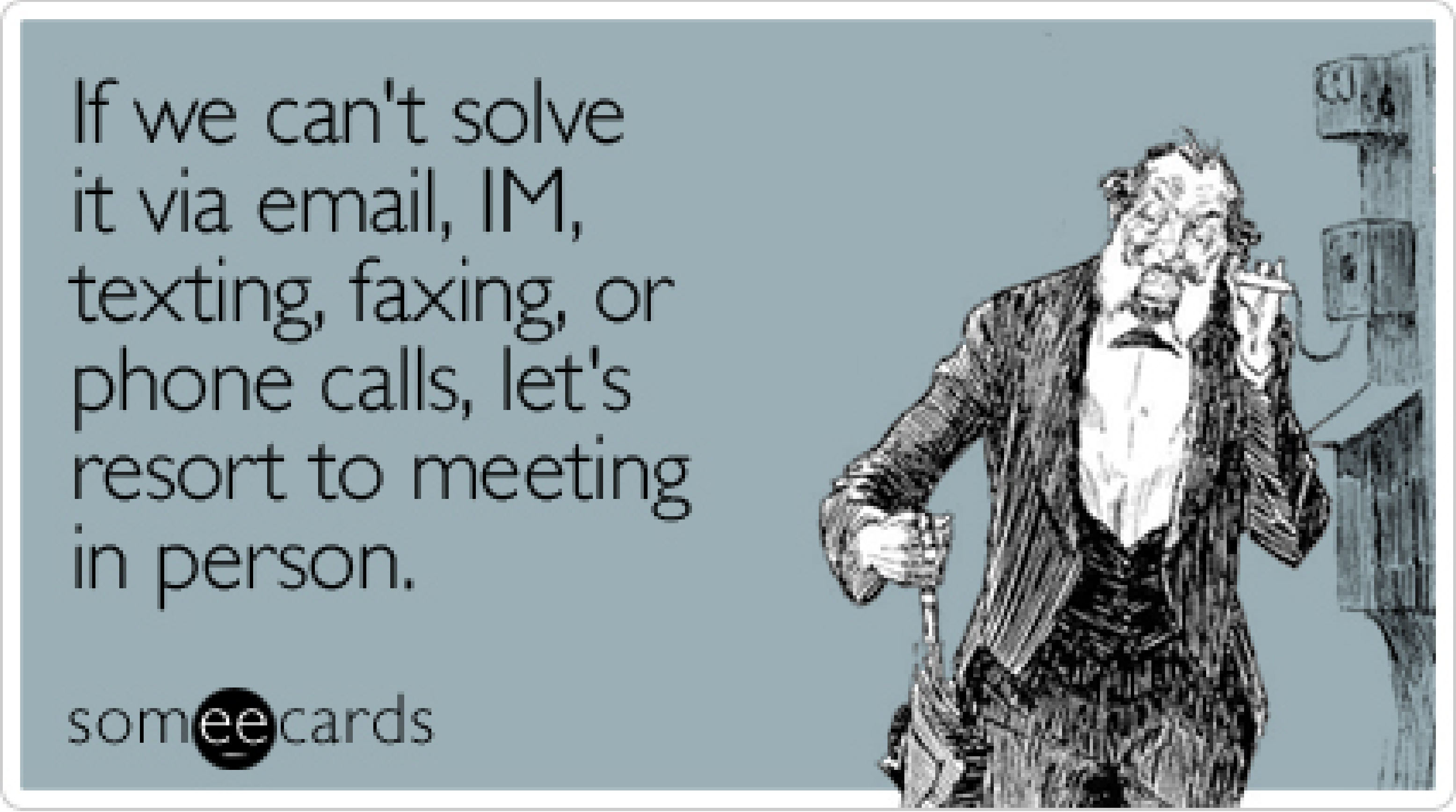
Vs.

The Challenges

- **AVT-126:** Common metrics and definitions; real world engine operation outside original design specification; access to in-service data; getting beyond ‘Valley of Death’ (TRL5)
- **AVT-128:** The size of the task for “intelligent engines” = ‘onboard’ systems; positioning of monitoring systems plus weight issues; high temperature electronics requirement
- **AVT-180:** Development of sensors in harsh engine environment (HPC→Combustor →Turbine →Exhaust); accurate & quantifiable data validated in the Test Cell
- **AVT-229:** Accuracy & format of data gathered & transferred; lack of coherent test protocols (24 papers)
- **AVT-306:** Transition from development to production; widening the instrumentation collaborative community

The Opportunities

- **Gas Turbine Instrumentation relationship established, so…**
  - Identify and agree components and sensors that can be ruggedized for 'quick wins' on legacy and future gas turbine engines
  - Agree to share real-world data in common format to validate design assumptions and inform off-design effects
  - Continue to engage with the wider instrumentation community, especially industry, to promote clear communication and understanding to resolve common problems, or…


If we can't solve it via email, IM, texting, faxing, or phone calls, let's resort to meeting in person.
someecards

What next…?

- **Further Collaboration**
  - Joint PIWG/EVI-GTI meetings and workshops

- **Further work in NATO STO**
  - AVT-ET-XXX – "Technologies for Distributed Engine Controls"

QUESTIONS…

"Insanity: doing the same thing over and over again and expecting different results."

Albert Einstein