Chapter 5 – UNIVERSAL SENSOR AND ACTUATOR REQUIREMENTS

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5.1 INTRODUCTION

The previous chapters have focused on the requirements for sensors and actuators for "More Intelligent Gas Turbine Engines" from the perspective of performance and operating environment. Even if a technology is available, which meets these performance requirements, there are still various hurdles to be overcome for the technology to transition into a real engine. Such requirements relate to TRL (Technology Readiness Level), durability, reliability, volume, weight, cost, etc. This chapter provides an overview of such universal requirements which any sensor or actuator technology will have to meet before it can be implemented on a product. The objective here is to help educate the researchers or technology developers on the extensive process that the technology has to go through beyond just meeting performance requirements. The hope is that such knowledge will help the technology developers as well as decision makers to prevent wasteful investment in developing solutions to performance requirements, which have no potential to meet the "universal" requirements. These "universal" requirements can be divided into 2 broad areas:

1) Technology value proposition; and
2) Technology maturation.

These requirements are briefly discussed in the following.

5.2 TECHNOLOGY VALUE PROPOSITION

A fundamental premise (beyond basic safety) for considering the incorporation of any component onto/into the engine is that it adds value. Some components will be considered intrinsic to the engine design and functionality (e.g. engine control, fuel system components, cycle temperature sensors), and as a result, their value is tied directly to the overall product's attributes (fuel burn, range, direct maintenance cost). All other non-intrinsic components added to the engine are required to provide some level of value that, at a minimum, mitigates the negative effects of its installation (weight, volume, energy consumption, installed losses).

In the best case, the value added will provide direct positive impact to the customer in terms of increased revenue opportunities, or via easily measured life-cycle cost reductions. But this does not always have to be the case. Value can also be gained via non-direct cost reductions for the customer, and often the OEM (Original Equipment Manufacturer) of the engine or aircraft most easily captures the value. In these cases, it is generally assumed that this value can be passed on to the customer in some fashion, in whole or in part.

One common way that value analysis is performed is via a calculation of customer net present value (NPV). This common metric allows for capture of the life cycle costs and benefits of the proposed component or feature. Typical evaluation elements include (but are not limited to) the following:

Impact on Revenue: Does the technology provide enhanced utilization rates, increased dispatch reliability, increased ETOPS (Extended-range Twin-engine Operational Performance Standards) availability, or performance improvement? Is the technology a performance enabler? If the answers to any of these value adding objectives is yes, then an assessment has to be made as to what impact will this technology have on the customer's revenue stream – how much can the revenue be increased over the life-cycle of the technology. Typically, sensors or actuators are part of an overall control or diagnostic technology. So the revenue impact has to be considered for the technology as a whole, and the value of the sensor or actuator has to be determined from its criticality for enabling the technology.

Impact on Cost: Any new technology impacts the cost to the customer in various ways. The first impact is the acquisition cost. How much will the cost of the engine go up if the technology were to be incorporated into the engine? The acquisition cost has to account for factors such as the non-recurring engineering development cost, recurring costs associated with buying the particular sensor/actuator from a vendor, cost of integrating the sensor/actuator into the engine, cost of spares, etc. Another important element of cost is that associated with maintenance. The reliability of the sensor/actuator and its impact on events such as aborted take-off, inflight engine shut-down, and aircraft diversions have a big influence on the operational costs of incorporating the technology. The labor and time cost associated with part removal, line maintenance, shop maintenance, repair, troubleshooting have to be factored in when calculating the overall impact of the technology on the life cycle cost of the engine.

Other: Other than revenue and cost, some other factors to be considered for sensors and actuators are impact on overall engine weight, the capability of the technology to fit into the specified volume (since real estate on an engine is at a premium), accessibility once installed onto/into the engine, cooling requirements, power and wiring requirements. Designing for ease of integration into the engine has to be an important element of developing any technology solutions to challenging sensor/actuator performance requirements.

5.3 TECHNOLOGY MATURATION

The process of moving a product, process or component towards maturity typically follows the development route as described in the Technology Readiness Level (TRL) definitions [5.1]. Business, manufacturing, legislative, etc., issues must be covered at an appropriate level at all stages.

The process typically follows a gated process involving formal reviews at specific stages, generally related to specific TRLs.

Any work within a business must have a business case, although up to TRL3 (proof of concept) this may be fairly loose. The level of investment will reflect the level of associated risk. The typical correlation is that at low TRLs, the risk is relatively high, so low levels of funding will be used in simple evaluations of the technical and business risks. As the TRL level increases, the level of understanding should rise and the level of risk should fall. Achievement of the higher TRLs inevitably requires much higher investment, although this is typically achieved with a much clearer business case and lower risk.

A gated review process is typically used to monitor and control the development and risk mitigation. Major formal reviews may be undertaken after TRL4 has been achieved, i.e. the component and/or system has been validated in a laboratory environment. At this stage, the basic technology will have been formulated together with the preferred embodiment as a practical device and the operational, business, etc., benefits should have been evaluated. This will provide a good prediction of the final implementation.

A higher investment will typically be needed to reach TRL6 (system/subsystem model or prototype demonstration in a relevant environment). After this, the concept will be expected to be suitable for design into a development product. The development gate at TRL6 will typically provide this final decision of whether to continue to product development and will have a much more rigorous business and application evaluation.

Once established as a product at TRL9 (actual system proven through successful mission operation), the system will be ready to enter routine service. Periodic reviews of the system are likely to continue throughout it's service life.

5.4 REFERENCE

[5.1] Appendix 1 – RTB Endorsed Proposed NATO Hardware TRL Definitions (24 September 2007).