Section 9D
Technology Readiness Level Scale

Appendix 9D – Technology Readiness Level Scale

TRL	Detailed Description	Example
TRL-1: Basic principles observed and reported	This is the lowest "level" of technology maturation. At this level scientific research begins to be translated into applied research and development.	(1) Basic properties of a new high-temperature nickel-based material. (2) Aerodynamic effects of a unique airfoil shape observed.
TRL-2: Technology concept and/or application formulated	Once basic physical principles are observed then at the next level of maturation practical applications of those characteristics can be "invented" or identified. At this level the application is still speculative: there is not experimental proof or detailed analysis to support the conjecture.	(1) New nickel-based alloy has characteristics that may be beneficial in a turbine disk. (2) Unique airfoil shape may provide an acoustic benefit in fan blades.
TRL-3: Analytical and experimental critical function and/or characteristic proof-of-concept	At this step in the maturation process active research and development (R&D) is initiated. This must include both analytical studies to set the technology into an appropriate context and laboratory-based studies to physically validate that the analytical predictions are correct. These studies and experiments should constitute "proof-of-concept" validation of the applications/concepts formulated at TRL-2.	(1) Perform stress analysis on turbine disk made of new material; perform pull test on material sample. (2) Use CFD tool to generate fan blade shape and to perform initial calculations of fan performance and aerodynamic interaction.
TRL-4: Component-level validation in laboratory environment	Following successful "proof-of-concept" work basic technological elements must be integrated to establish that the "pieces" will work together to achieve concept-enabling levels of performance for a component material, etc. This validation must support the concept that was formulated earlier and should also be consistent with requirements of potential system applications. The validation is relatively "low-fidelity" compared to the eventual system; it could be composed of ad hoc discrete components in a lab.	(1) Spin-test disk manufactured from new material. (2) Sub-scale fan rig test with new blades.
TRL-5: Component-level validation in relevant environment	At this level the fidelity of the component and/or breadboard being tested has to increase significantly. The basic technological elements must be integrated with reasonably realistic supporting elements so that the total applications (component-level sub-system level or system-level) can be tested in a "simulated" or somewhat realistic environment. One or several new technologies may be involved in the demonstration.	(1) Run turbine wheel using new disk material and cooled blades in turbine rig. (2) Full-scale fan with representative stator configuration(s) in rig/demo engine.
TRL-6: System/subsystem model or prototype demonstration in a relevant environment	A major step in the level of fidelity of the technology demonstration. At TRL-6 a representative model or prototype system well beyond ad hoc "patch-cord" or discrete component level breadboarding is tested in a relevant environment (e.g., relevant temperatures/speeds/size/loading. Not all technologies will undergo a TRL-6 demonstration: at this point the maturation step is driven more by management confidence than by R&D requirements. The demonstration might represent an actual system application or it might only be similar to the planned application but using the same technologies. At this level several new technologies may be integrated into the demonstration.	(1) HP turbine using new disk material integrated into representative engine and tested. (2) Fan module designed with new fan blade integrated into representative engine and tested.

Technology Readiness Level Scale (cont.)

TRL	Detailed Description	Example
TRL-7: System prototype demonstration in flight	TRL-7 is a significant step beyond TRL-6 requiring an actual system prototype demonstration in a flight/space environment. It has not always been implemented in the past. In this case the prototype should be near or at the scale of the planned operational system and the demonstration must take place in an actual operating environment. The driving purposes for achieving this level of maturity are to assure system engineering and develop customer management confidence (more than for purposes of technology R&D). Therefore, the demonstration must be of a prototype of that application. Not all technologies in all systems will go to this level. TRL-7 would normally only be performed in cases where the technology and/or subsystem application is mission critical and relatively high risk.	First flight of hypothetical engine YY with new fan in demonstrator or actual vehicle as with above example.
TRL-8: Actual system completed and "flight qualified" through test and demonstration	By definition, all technologies being applied in actual systems go through TRL-8. In almost all cases this level is the end of true "system development" for most technology elements.	(1) Qualification of new engine for military service. (2) Certification (Part 33) of new engine for commercial service.
TRL-9: Actual system "flight proven" on operational vehicle	By definition, all technologies being applied in actual systems go through TRL-9. In almost all cases the last "bug fixing" aspects of true "system development" are complete. Ready for entry into service.	New engine enters service or is in service on airframe in vehicle, etc.