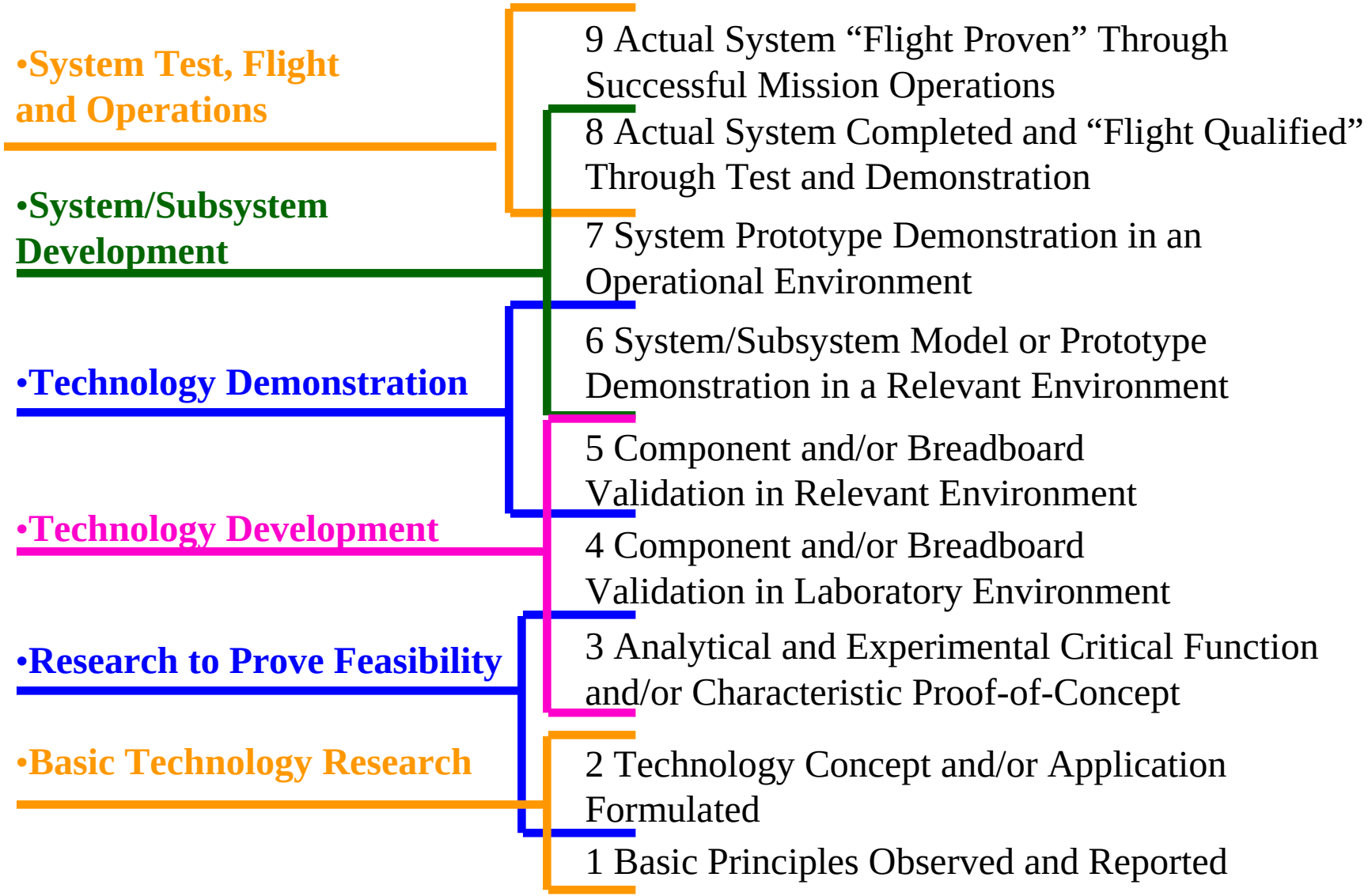
Technology Readiness Levels

Standard Definitions

UAV ATRB

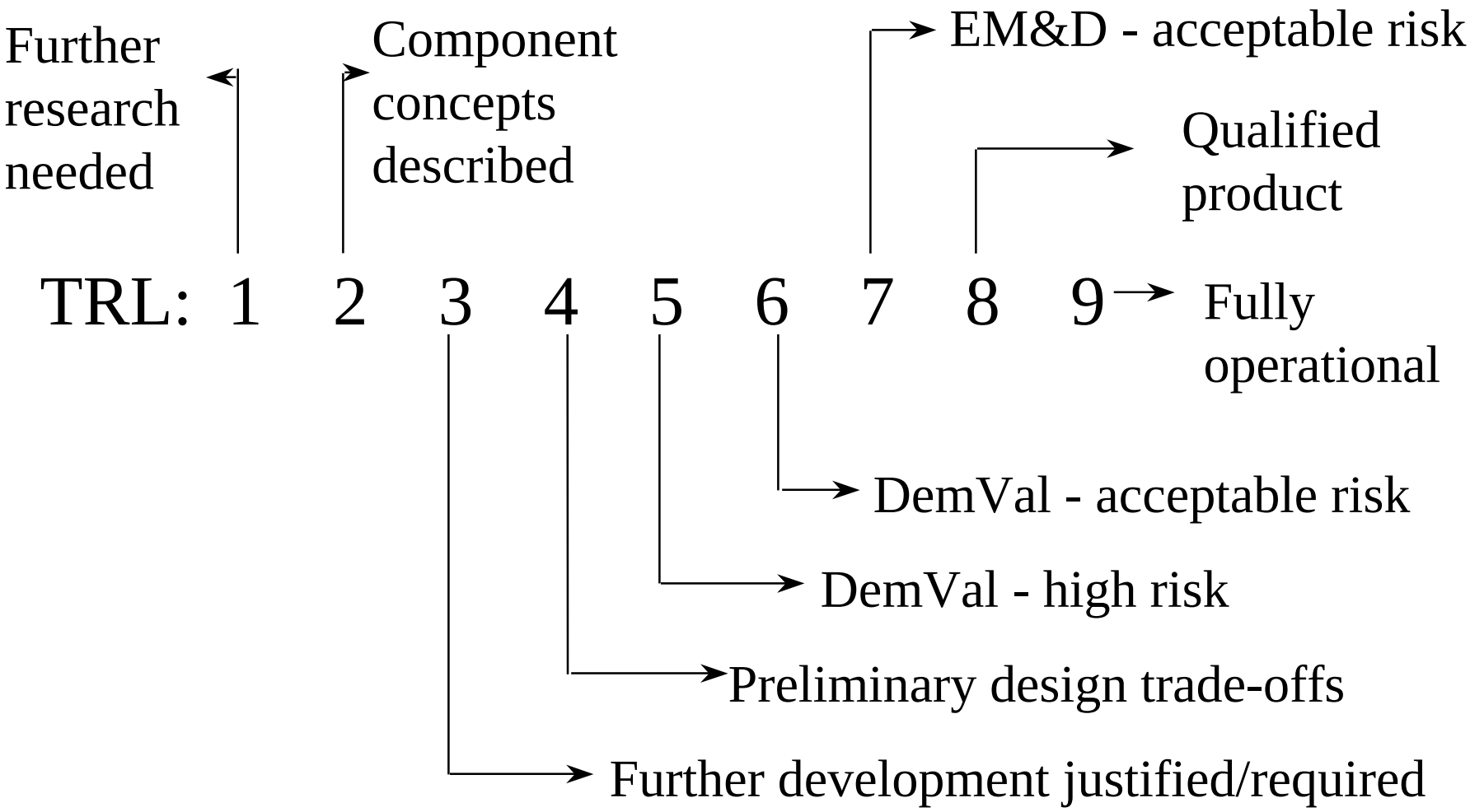
Technology Readiness Levels

UAV ATRB



Technology Readiness Levels

APPLICATION:



Technology Readiness Levels

Definitions:

Hardware - any piece of physical equipment that is part of the technology under consideration, eg. structural component, w.t.model,

Model - the complete description of the performance and cost of the technology, including simulation models

Test Environment - parameters of the demo or test that provide the data to define the TRL, eg. simulation, w.t. test, component or integrated

Products - the data that is available from the activity defining the TRL, ranges from analytical calculations through ground/flt demo results

Uncertainty - an assessment of the demo data products that relate any uncertainties in the technology model to the risk of system integration

Transition Readiness - judgement of how ready the technology is for incorporation into the development phase of a system application

Risk - Judgment of Probability & Consequence of Failure to System

Technology Readiness Level 3

Analytical & Experimental Critical Function and/or Characteristic Proof-of-Concept:

- Testing of Breadboard or Generic Hardware
  -- e.g. parametric wind tunnel testing
  -- e.g. sub-scale components

- First-Order Analytical Models Developed
  -- contributions towards goals predicted, typically single technology
  -- but not directly correlated with data
  -- e.g. detailed CFD predictions

PRODUCTS: Technology Models but Many Uncertainties

TECHNOLOGY CHARACTERISTICS BEING DEFINED
- Concept Proven for Further Development, Potential Transition
- Uncertainties are with System Integration

Technology Readiness Level 4

Component and/or Breadboard Validation in a Laboratory Environment:

- Hardware Must be Representative of the Technical Concept Approach Suitable for Flight Articles

- Lab/Ground Demo is Relevant Test Environment
  -- e.g. wind tunnel test of chosen configuration
  -- e.g. simulation of moderate fidelity

- Analytical Models Defined/Cost Predictions Made
  -- initial test data correlations made

PRODUCTS: Design Data and Performance Predictions

TECHNOLOGY APPROPRIATE FOR DESIGN TRADE-OFFS
- Data Shows Technology Has Probable Transitionability
- System Integration Issues Not Well Defined

Technology Readiness Level 5

Component and/or Breadboard Validation in a Relevant Environment:

- Testing of Hardware of Appropriate Scale
- Hardware Should be Functionally Equivalent to Flight Articles
  - may not be flight weight, material, etc.
- Relevant Test Environment is High Fidelity Ground Demo or Simulation with System Interactions Identified
- Analytical Model of Integrated System
  -- some test correlations made with good agreement

PRODUCTS: Good Estimates of Performance and Cost Impacts

TECHNOLOGY READY FOR DETAILED DESIGN STUDIES
- Good Transitionability, Integration Issues Defined, High Risk

Technology Readiness Level 6

System/Subsystem Model or Prototype Demonstration in a Relevant Environment:

- Testing of Hardware of Appropriate Scale
- Hardware Must be Actual Flight Articles or "Flight Type"
- Relevant Test Environment - High Fidelity Ground Demo/Simulation with Components that "Could Fly"
  OR Low Fidelity Flight Test, eg Restricted Flight Envelope
- Analytical Model for the Technology Integrated into a Flight System
  -- acceptable uncertainties, well correlated with test data

PRODUCTS: Substantiated Performance and Cost + Design Data

INTEGRATION of TECHNOLOGY IS WELL DEFINED
- Actual Test Data Shows Minor Risk for Transition

Technology Readiness Level 7

System Prototype Demonstration in an Operational Environment:

- Testing of Hardware of Full Scale Actual Flight Articles
- Flight in Appropriate Envelope is Relevant Environment for Critical Technologies or Ground Demo of Flight Hardware
- Analytical & Simulation Models High Fidelity
  -- fully validated with test data
  -- uncertainties of system integration and application are small
- Uncertainty is Low, System Integration Demonstrated

PRODUCTS: Design Criteria + Validated Performance and Cost

TECHNOLOGY IS WELL SUBSTANTIATED WITH TEST DATA
- Validated as being Ready for Low-Risk Transition

Technology Readiness Level Progression

UAV ATRB

LEVEL	1 & 2	3	4
Hardware	N/A	Breadboard	Representative
Models	Order of magnitude	Analytical, 1st order	Analytical, with some test data comparison
Test environment	N/A	Lab	Lab
Products	Analytical results	Technology models	Models extended with test data
Uncertainty	Major/unknown	Major	High
Transition Readiness	Unknown feasibility	Technology potential, but unknown implementation	Probable, but undefined system application issues

Technology Readiness Level Progression

UAV ATRB

LEVEL	5	6	7
Hardware	Functionally equiv.	Flight type	Flight articles
Models	Good, comparison with measured interactions	Models correlated with integrated test data	Fully validated against flight test data
Test environment	Ground demo, with actual components	Hi Fi ground or limited flt	High fidelity ground or flight test
Products	Design data	Performance and cost of integrated system	Design criteria plus validated data
Uncertainty	Medium	Minor	Low
Transition Readiness	Good, system interactions identified	V Good, with system integration effects measured in demo	Ready

Technology Readiness Level	Hardware	Demonstration Environment	Risk for PDRR	Risk for EMD
1- Basic principles observed and reported	Paper studies	Not applicable	Unacceptable	Unacceptable
2 – Technology concept and/or application formulated	Paper studies	Not applicable	Unacceptable	Unacceptable
3 – Analytical and experimental critical function and/or characteristic proof of concept	Paper studies/individual components of breadboard	Laboratory	Unacceptable	Unacceptable
4 – Component and/or breadboard validation in laboratory environment	Low fidelity, integrated breadboard	Laboratory	Unacceptable	Unacceptable
5 – Component and/or breadboard validation in relevant environment	High fidelity Breadboard	High fidelity lab or flying test bed	High risk	Unacceptable
6 – System/subsystem model or prototype demonstration in a relevant environment	Engineering prototype	High fidelity lab or low fidelity flying test bed	Acceptable risk	High risk
7 – System prototype demonstration in an operational environment	Engineering prototype	High fidelity flying test bed	Low risk	Acceptable risk
8 – Actual system completed and "flight qualified" through test and demonstration	Operational prototype	Integrated and flight tested in target aircraft under operating condition (i.e. DT&E)	Qualified product	Low risk – Qualified product
9 - Actual system flight proven through successful mission operations	Operational system	Operational aircraft conducting real or simulated operational missions	NA	NA