NASA Cost Symposium

Multivariable Instrument Cost Model-TRL (MICM-TRL)

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RAO Instrument Cost Model Drivers

- **SICM (366 instruments)**
  - Weight
  - Instrument Family
  - Heritage

- **MICM-96, Version 2 (313 instruments)**
  - Weight
  - Power
  - Data Rate
  - Schedule
  - Year of Technology
  - Instrument Family
  - Mission Class

- **MICM-90, Version 1 (189 instruments)**
  - Weight
  - Power
  - Data Rate
  - Year of Technology
  - Instrument Family
  - Mission Class

- **MICM-TRL, Version 3 (310 instruments)**
  - Weight
  - Power
  - Data Rate
  - Schedule
  - Year of technology
  - Instrument Family
  - Mission Class
  - Technology Readiness Level

MICM-TRL
Cost Drivers

Instrument Weight (WT)

This independent variable is the total instrument dry weight in pounds.

Instrument Power (PWR)

Instrument power is the **peak** power consumed by the instrument in watts.

Instrument Data Rate (DRT)

This cost driver is the instrument's **peak** uncompressed data rate coming into the instrument sensor expressed in kilobits per second.

Instrument Duration to Delivery (DEL)

This is the number of months from Authority to Proceed (ATP) to instrument delivery.

MICM-TRL
Cost Drivers (continued)

Instrument Year of Technology (YR)

This variable is stated in terms of the number of years after 1960 that launch occurs. The greater the number of years, the more recent the technology used in developing the instrument. Excluding the impact of inflation, the trend in many high technology areas is that per unit costs decline over time.

Instrument Family (FAM)

This variable distinguishes among types of instruments in terms of scientific applications and physical makeup (Level 1 - 8 categories; Level 2 - 18 families).

Mission Class (CLS)

The mission class variable accounts for differences in instrument reliability and complexity resulting from the type of mission flown. The MICM mission class variable is a function of two reliability concepts: design life and reliability classes.

Technology Readiness Level (TRL)

This cost driver quantifies the status of technology readiness on a scale from 1 to 9, with 1 being the least ready and 9 the most ready. The value for TRL to be used as an input to MICM preferably is determined by the objective approach described using the flow charts.

RAO MICM-TRL
CHARACTERISTICS FOR EVALUATING TECHNOLOGY READINESS LEVELS FOR SPECIFIC PROPOSED INSTRUMENTS

TRL 1: Basic principles observed and reported

- Very little investment in proposed instrument
- Scientific papers written on basic principles
- Essentially no experimental studies
- No previous flight experience with the proposed instrument
- No Phase A studies
- No definition approach selected for any flight application

TRL 2: Technology concept and/or application formulated

- Some Phase A studies conducted for the proposed instrument in a flight application
- Important trades have been studied and documented
- Limited experimental studies
- No previous flight experience with the proposed instrument

TRL 3: Analytical and experimental critical function and/or characteristic proof of concept

- An integrated Phase A study was completed for proposed instrument in a flight application
- Analytical and experimental studies conducted that demonstrate viability of critical functions and provide proof of concept; studies may be Supporting Research Technology (SRT) studies and Advanced Research Technology (ART) studies
- Initial weight and power allocations at instrument level have been made
- No previous flight experience

TRL 4: Component and/or breadboard validation in <u>laboratory</u> environment

- Key instrument components and/or breadboards of the proposed instrument have been validated in laboratory environment, which may have included balloon or suborbital flights
- Instrument definition study (Phase B) has been completed
- Key trade studies have been conducted
- Detailed weight and power requirements are known
- There is a first cut at weight and design margins

TRL 5: Component and/or breadboard validation in <u>relevant</u> environment

- Key instrument components and/or breadboards of the proposed instrument have been validated by <u>orbital</u> flight
- Instrument definition study (Phase B) has been completed
- Key trade studies have been conducted
- Detailed weight and power requirements are known
- Principal Investigator is in a position to establish firm weight and design margins and schedule

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CHARACTERISTICS FOR EVALUATING TECHNOLOGY READINESS LEVELS FOR SPECIFIC PROPOSED INSTRUMENTS

TRL 6: System/subsystem model or prototype demonstration in a relevant environment (ground or space)

- Subsystem prototypes or models of the proposed instrument have been successfully tested under space conditions in orbital flight
- Proposed instrument will require substantial modifications for proposed mission

TRL 7: System prototype demonstration in a space environment

- Prototype of the proposed instrument has been successfully tested in a recent (i.e., within 3 years) flight demonstration in orbital flight
- Mission-like flight functions conducted in flight demonstration
- Proposed instrument will require minor modifications for proposed mission

TRL 8: Actual system completed and "flight qualified" through test demonstration (ground and space)

- Predecessor instrument has been successfully tested in a recent (i.e., within 3 years) flight demonstration in orbital flight as well as successful ground end-to-end tests
- Mission-like data obtained in previous flight
- Proposed instrument will have no more than very minor modifications

TRL 9: Actual system "flight proven" through successful mission operations

- Predecessor instrument has been operationally proven in a recent (i.e., within 3 years) full space mission (not suborbital, balloon or test demonstration) that was a similar mission to the one planned for the proposed instrument
- Actual mission-required data obtained in previous flight
- Proposed instrument is a follow-on to the predecessor instrument and has essentially the same design or only slight structural modifications
- Proposed instrument will not have improvements in sensors
- Proposed instrument will not have any changes in calibration techniques
  Proposed mission changes will be very minor for science objectives and orbit parameters

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Chart 1: Guide to Initial TRL Determination (Before Adjustments) for Proposed Instrument

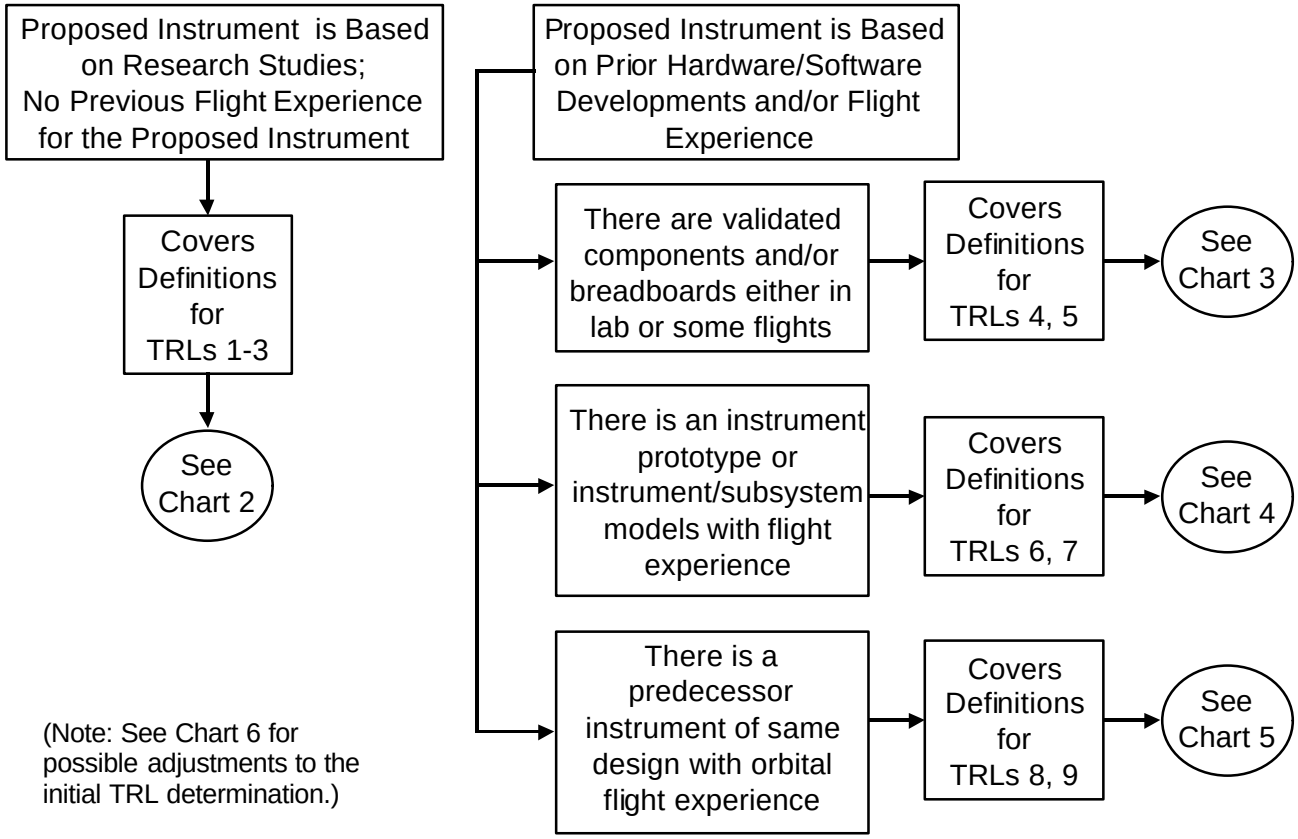

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Chart 2: Proposed Instrument Based on Research Studies -- No Previous Flight Experience for Proposed Instrument

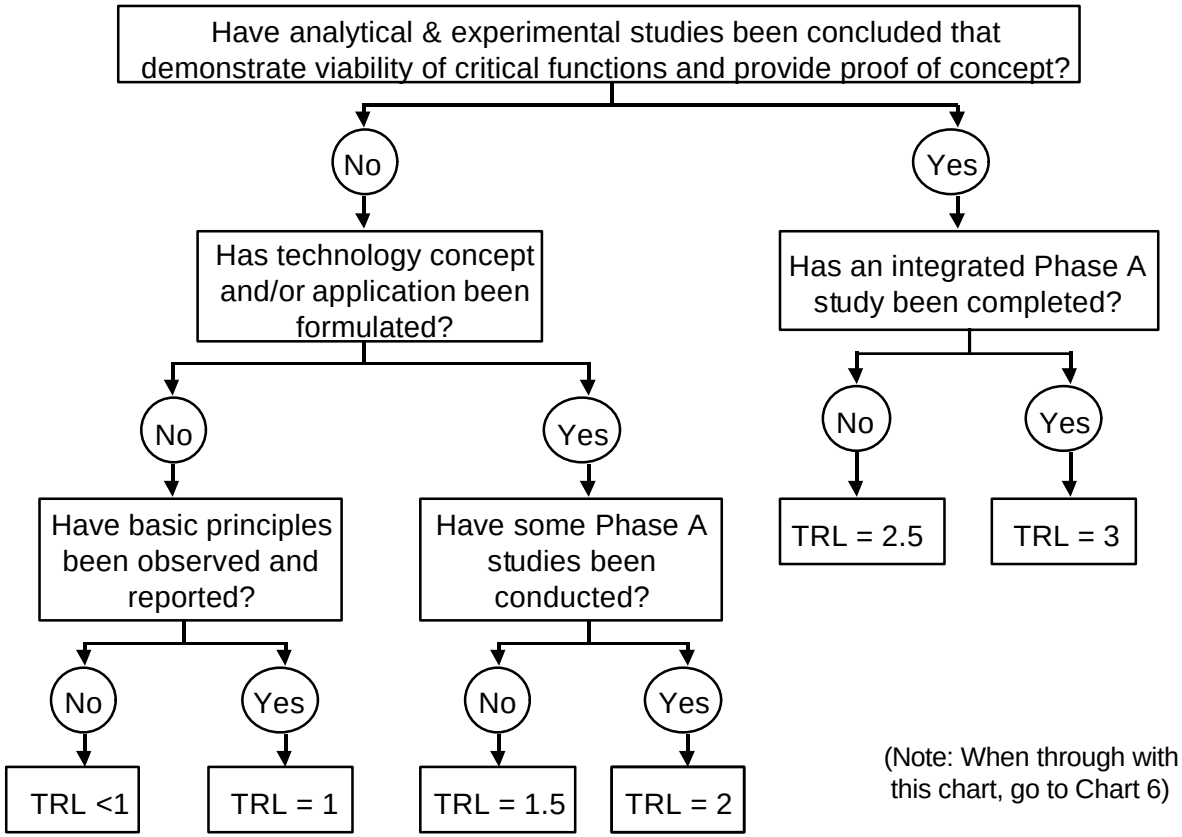

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Chart 3: Proposed Instrument Has Validated Components and/or Breadboards

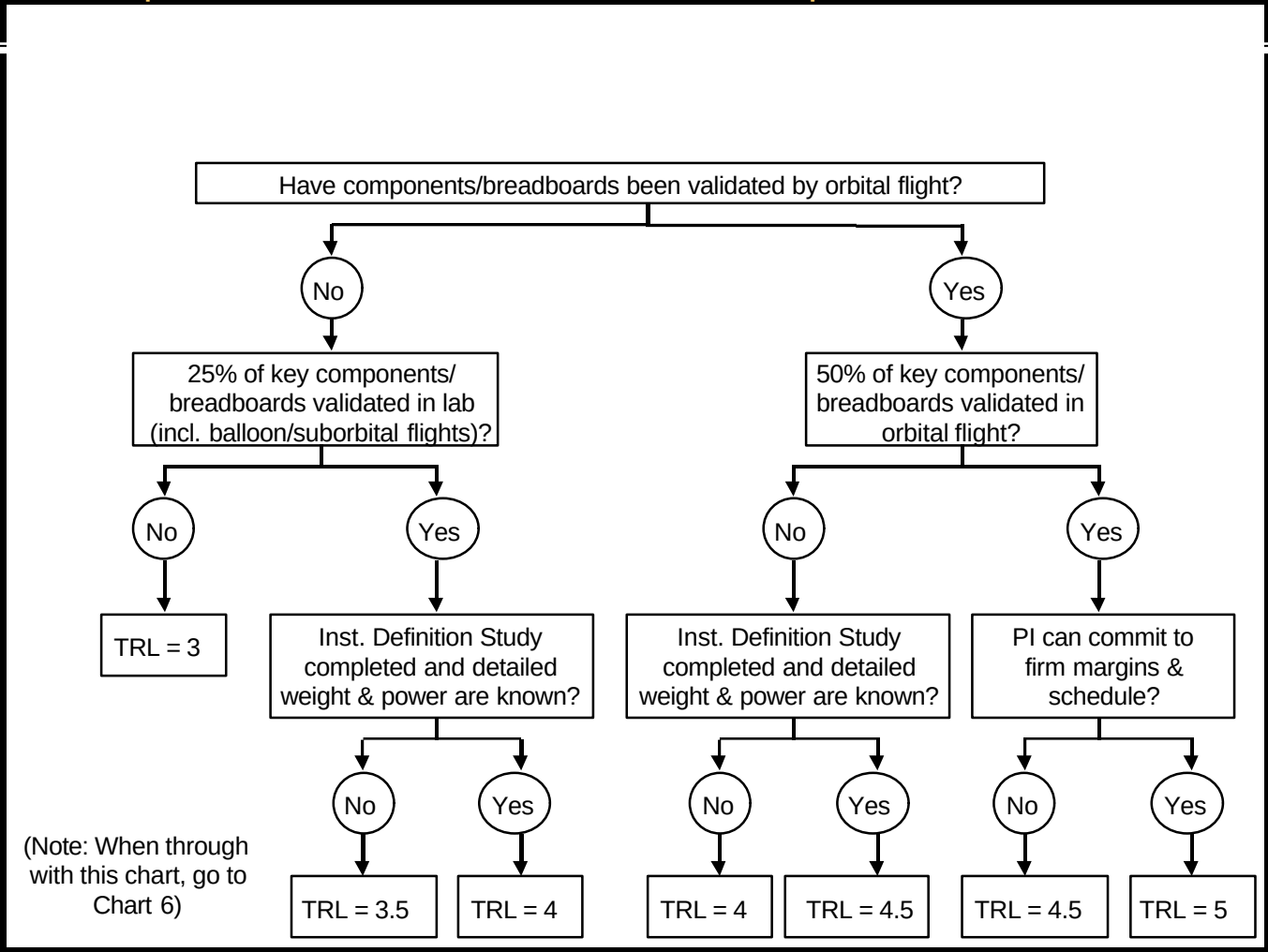

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Chart 4: There is an Instrument Prototype or are Instrument/Subsystem Models for the Proposed Instrument

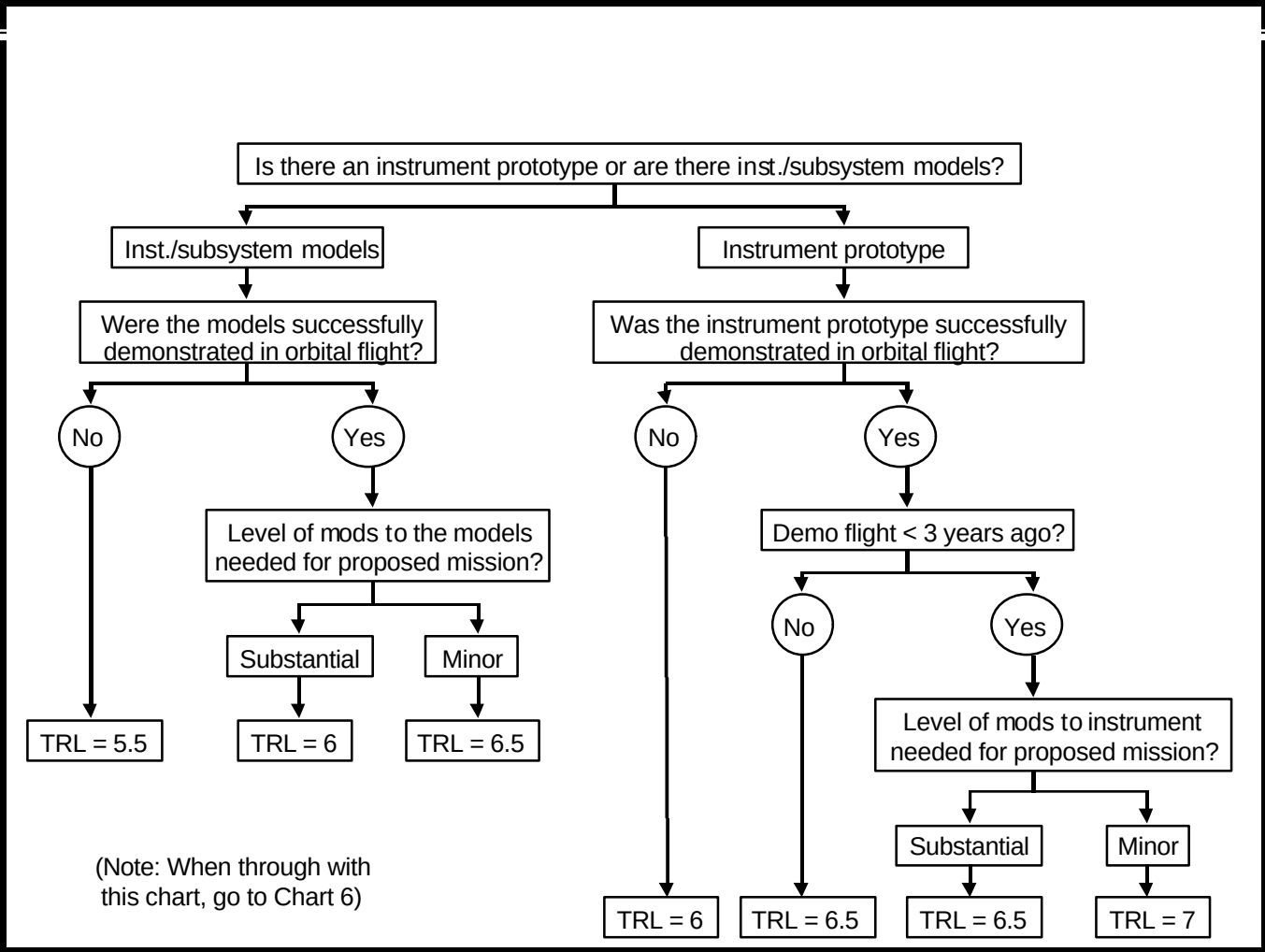

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Chart 5: Proposed Instrument Has Predecessor of Same Design

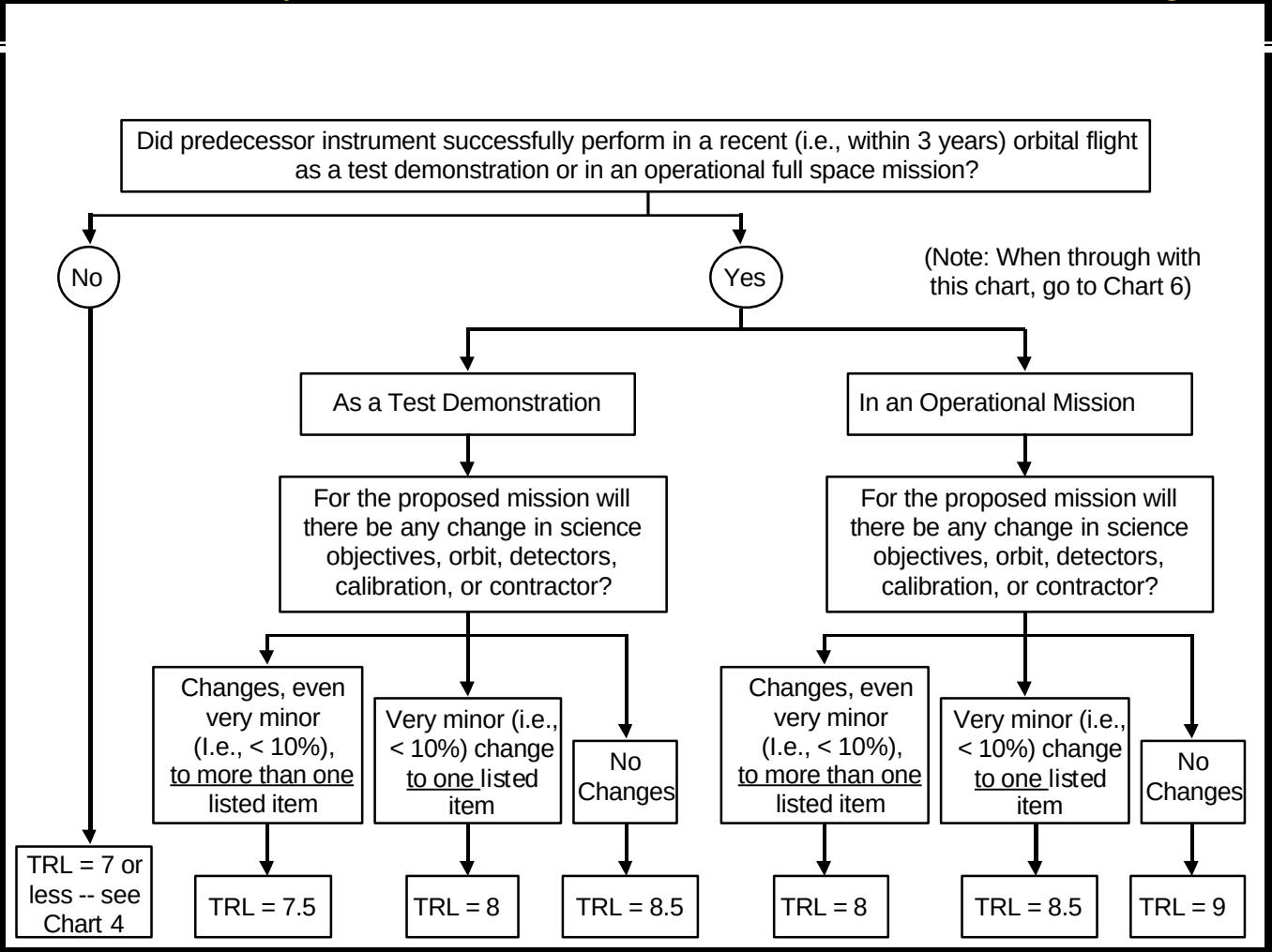

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Chart 6: Guide to TRL Adjustments

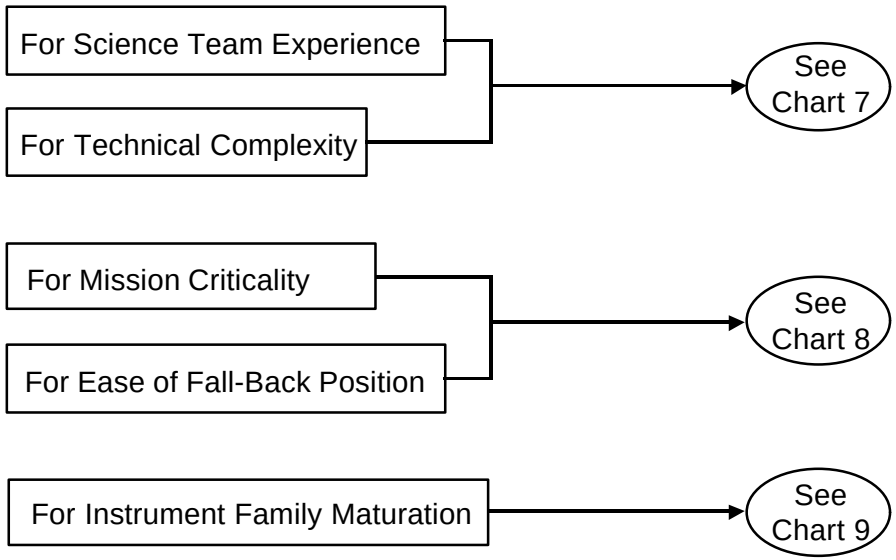

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Chart 7: TRL Adjustments for Science Team Experience and Technical Complexity

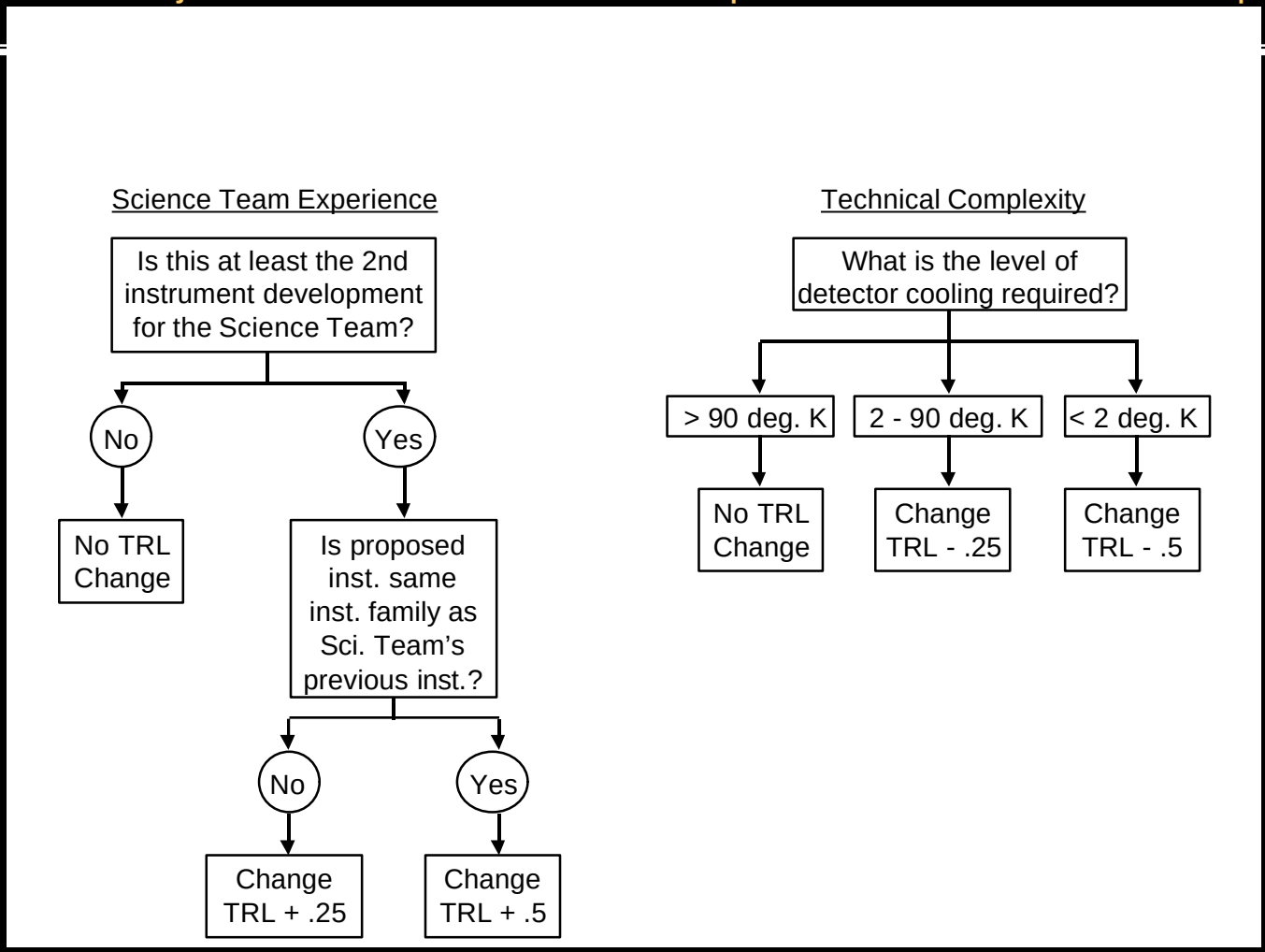

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Chart 8: TRL Adjustments for Mission Criticality and Ease of Fall-Back Position

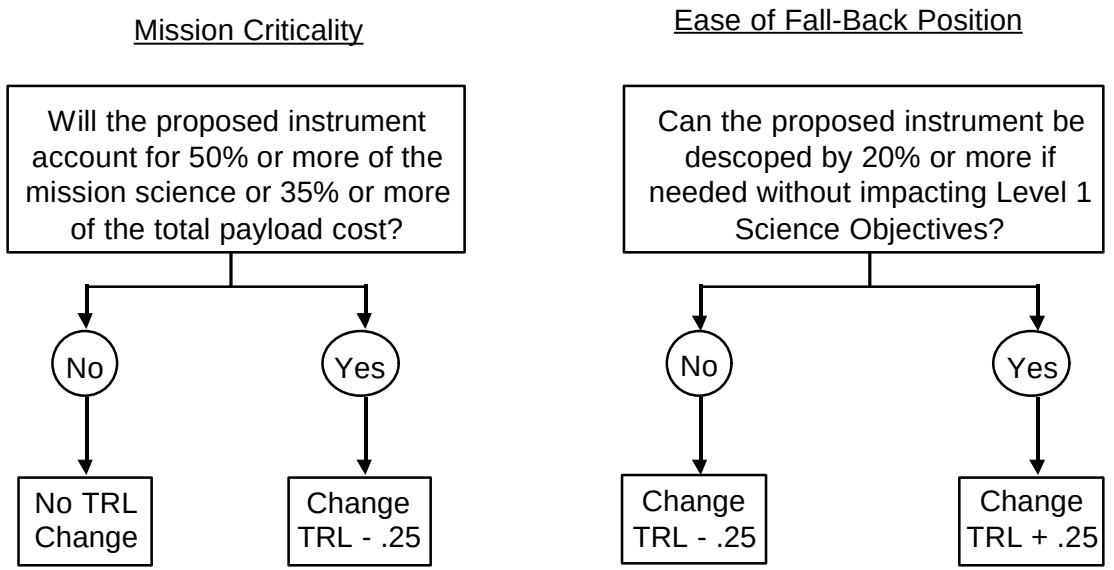

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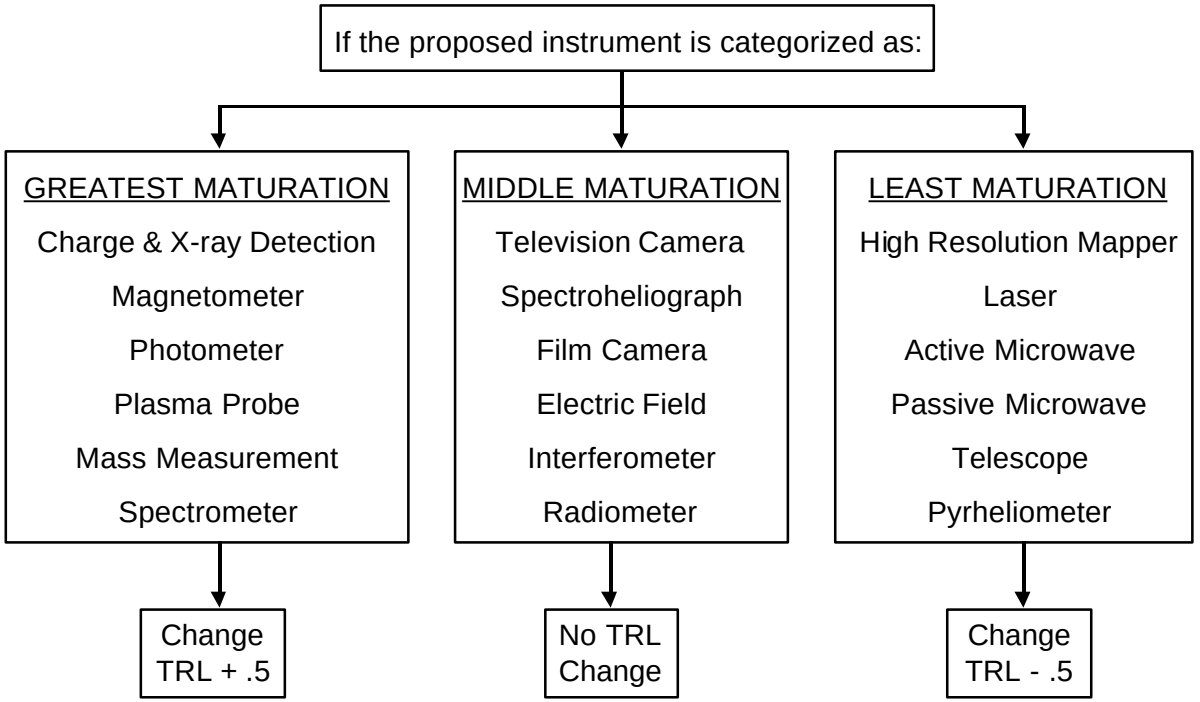
Chart 9: TRL Adjustments for Instrument Family Maturation



MICM-TRL
Model Outputs

- Prototype
- Protoflight
- Major Modification
- Minor Modification
- Follow On

MICM-TRL
Summary

- Enhancements from MICM-96
  - Schedule variable redefined (ATP -> delivery vs. ATP -> launch)
  - Addition of TRL variable
- Advantages
  - Spreads the Input Risk
  - Wide Validity Range
  - Combined Effects
  - Complexity and Reliability
  - Technology Readiness and Risk