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

- **MICM-96, Version 2 (313 instruments)**
  - Weight
  - Power
  - Data Rate
  - Schedule
  - 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

- **SICM (366 instruments)**
  - Weight
  - Instrument Family
  - Heritage
**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.
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 laboratory 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 relevant environment
• Key instrument components and/or breadboards of the proposed instrument have been validated by orbital 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
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
Chart 1: Guide to Initial TRL Determination (Before Adjustments) for Proposed Instrument

- Proposed Instrument is Based on Research Studies; No Previous Flight Experience for the Proposed Instrument
  - Covers Definitions for TRLs 1-3
    - See Chart 2

- Proposed Instrument is Based on Prior Hardware/Software Developments and/or Flight Experience
  - There are validated components and/or breadboards either in lab or some flights
    - Covers Definitions for TRLs 4, 5
      - See Chart 3
  - There is an instrument prototype or instrument/subsystem models with flight experience
    - Covers Definitions for TRLs 6, 7
      - See Chart 4
  - There is a predecessor instrument of same design with orbital flight experience
    - Covers Definitions for TRLs 8, 9
      - See Chart 5

(Note: See Chart 6 for possible adjustments to the initial TRL determination.)
Have analytical & experimental studies been concluded that demonstrate viability of critical functions and provide proof of concept?

No

Has technology concept and/or application been formulated?

No

Have basic principles been observed and reported?

No

TRL <1

Yes

TRL = 1

Yes

TRL = 1.5

Have some Phase A studies been conducted?

No

TRL = 2

Yes

TRL = 2

Has an integrated Phase A study been completed?

No

TRL = 2.5

Yes

TRL = 3

(Note: When through with this chart, go to Chart 6)
Chart 3: Proposed Instrument Has Validated Components and/or Breadboards

Have components/breadboards been validated by orbital flight?

No

25% of key components/breadboards validated in lab (incl. balloon/suborbital flights)?

No

TRL = 3

Yes

Inst. Definition Study completed and detailed weight & power are known?

No

TRL = 3.5

Yes

TRL = 4

Yes

Inst. Definition Study completed and detailed weight & power are known?

No

TRL = 4

Yes

TRL = 4.5

Yes

Inst. Definition Study completed and detailed weight & power are known?

No

TRL = 4.5

Yes

PI can commit to firm margins & schedule?

No

TRL = 5

Yes

(Note: When through with this chart, go to Chart 6)
Chart 4: There is an Instrument Prototype or are Instrument/Subsystem Models for the Proposed Instrument

Is there an instrument prototype or are there inst./subsystem models?

Inst./subsystem models

Were the models successfully demonstrated in orbital flight?

No

Yes

Level of mods to the models needed for proposed mission?

Substantial

TRL = 5.5

Minor

TRL = 6

TRL = 6.5

Instrument prototype

Was the instrument prototype successfully demonstrated in orbital flight?

No

Demo flight < 3 years ago?

No

Yes

Level of mods to instrument needed for proposed mission?

Substantial

TRL = 6

Minor

TRL = 6.5

TRL = 6.5

TRL = 7

(Note: When through with this chart, go to Chart 6)
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Chart 5: Proposed Instrument Has Predecessor of Same Design

Did predecessor instrument successfully perform in a recent (i.e., within 3 years) orbital flight as a test demonstration or in an operational full space mission?

No

As a Test Demonstration

For the proposed mission will there be any change in science objectives, orbit, detectors, calibration, or contractor?

Changes, even very minor (i.e., < 10%), to more than one listed item

TRL = 7 or less -- see Chart 4

TRL = 7.5

TRL = 8

TRL = 8.5

Yes

In an Operational Mission

For the proposed mission will there be any change in science objectives, orbit, detectors, calibration, or contractor?

Changes, even very minor (i.e., < 10%), to more than one listed item

Very minor (i.e., < 10%) change to one listed item

No Changes

Very minor (i.e., < 10%) change to one listed item

No Changes

Very minor (i.e., < 10%) change to one listed item

No Changes

(No Changes

TRL = 7.5

TRL = 8

TRL = 8.5

TRL = 8.5

TRL = 9

(Note: When through with this chart, go to Chart 6)
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Chart 6: Guide to TRL Adjustments

For Science Team Experience
See Chart 7

For Technical Complexity

For Mission Criticality
See Chart 8

For Ease of Fall-Back Position

For Instrument Family Maturation
See Chart 9
Chart 7: TRL Adjustments for Science Team Experience and Technical Complexity

**Science Team Experience**

Is this at least the 2nd instrument development for the Science Team?

- **No**
  - No TRL Change

- **Yes**
  - Is proposed inst. same inst. family as Sci. Team’s previous inst.?
    - **No**
      - Change TRL + .25
    - **Yes**
      - Change TRL + .5

**Technical Complexity**

What is the level of detector cooling required?

- > 90 deg. K
  - No TRL Change
- 2 - 90 deg. K
  - Change TRL - .25
- < 2 deg. K
  - Change TRL - .5
Chart 8: TRL Adjustments for Mission Criticality and Ease of Fall-Back Position

**Mission Criticality**

Will the proposed instrument account for 50% or more of the mission science or 35% or more of the total payload cost?

- **No**
  - No TRL Change
- **Yes**
  - Change TRL - .25

**Ease of Fall-Back Position**

Can the proposed instrument be descoped by 20% or more if needed without impacting Level 1 Science Objectives?

- **No**
  - Change TRL - .25
- **Yes**
  - Change TRL + .25
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Chart 9: TRL Adjustments for Instrument Family Maturation

If the proposed instrument is categorized as:

**GREATEST MATURATION**
- Charge & X-ray Detection
- Magnetometer
- Photometer
- Plasma Probe
- Mass Measurement
- Spectrometer
  
  Change TRL + .5

**MIDDLE MATURATION**
- Television Camera
- Spectroheliograph
- Film Camera
- Electric Field
- Interferometer
- Radiometer
  
  No TRL Change

**LEAST MATURATION**
- High Resolution Mapper
- Laser
- Active Microwave
- Passive Microwave
- Telescope
- Pyrheliometer
  
  Change TRL - .5
MICM-TRL
Model Outputs

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