Frontier Technology Inc.

Condition-Based Calibration for Electro-Optical Infrared Sensor Systems

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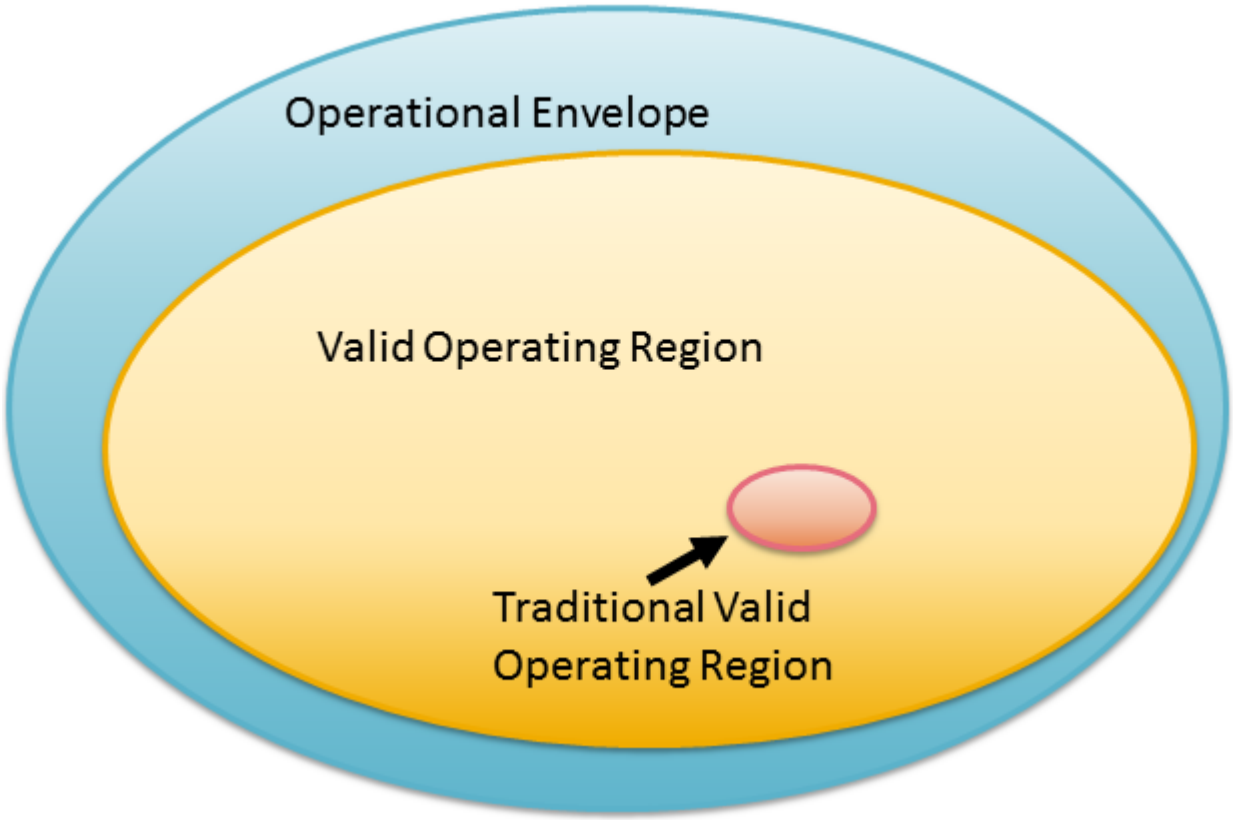
Motivation

- There is an increasing need for rapid (near real-time) calibration of electro-optical infrared (EOIR) sensors in operational settings either on orbit or airborne
  - Short-duration airborne sensors (sounding rockets or balloon borne)
  - Requirement for rapid response EOIR sensors
  - EOIR sensor operating in transient conditions or thermal equilibrium
- Creation of actionable sensor data shortly after deployment
- Ability to produce calibrated data on-board or on ground, with minimal manual supervision

Comparison to Traditional Calibration Method

- **Ideally, sensors would have radiometric calibration sources on-board and could perform absolute calibration as required over the full operational envelope of the sensor**
- **In absence of an on-board calibration source, this empirical calibration method allows condition-based calibration**
- **Could be used with an on-board source, either as a check or as an additional process to extend calibration envelope**
- **Questions need to be answered as to whether it is cheaper, better, or more reliable to use an empirical calibration method instead of, or in addition to, an on-board source**

Parameter Space for Sensor Operations



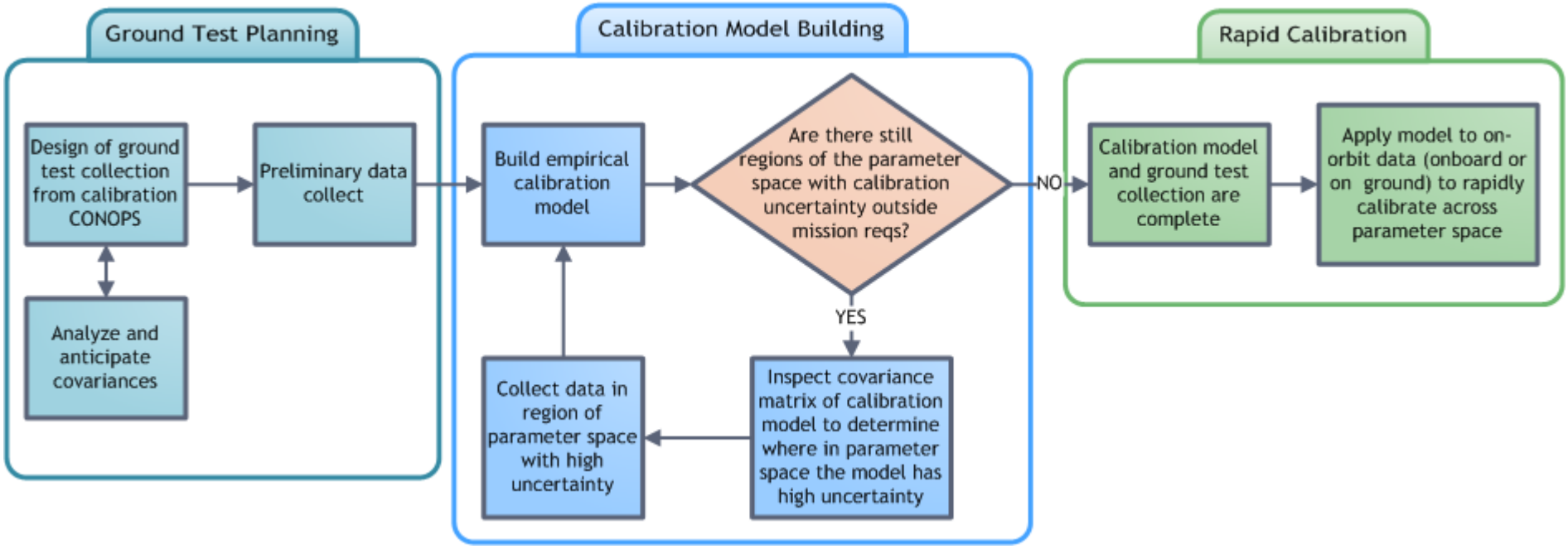
Operational Envelope is where sensor operates

VOR is where it produces calibratable data

TVOR is the subset of VOR expected for nominal on-orbit operations

Approach

- **Autonomous rapid on-orbit calibration method requires planning the ground test to collect sufficient data to support creation of an empirical calibration model**



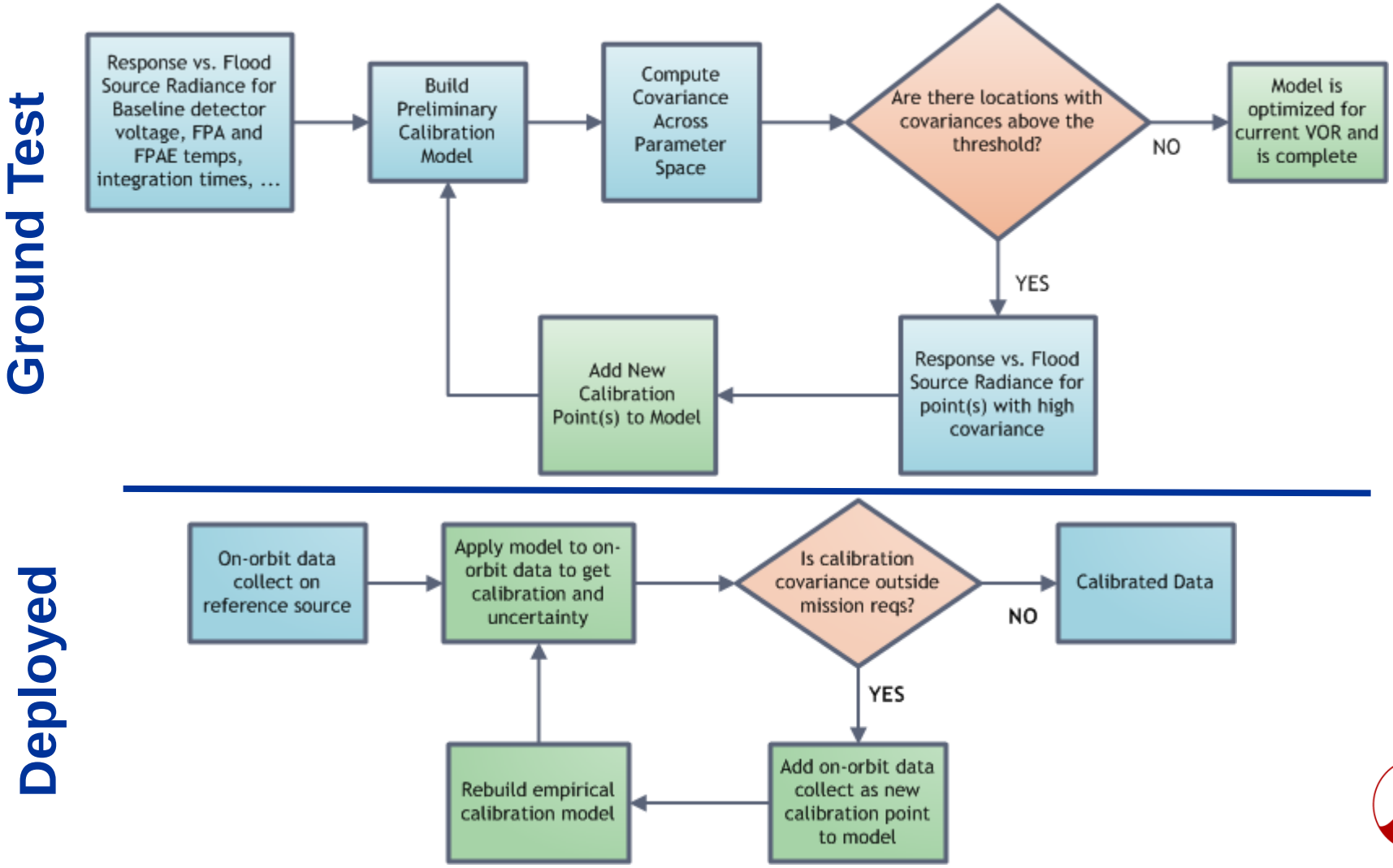
- **On-orbit data can also be added to model to improve calibration where ground test did not measure**

Ground Test Planning

- Optimize the FPA operating parameters (input voltages, integration times, operating temp): mission Traditional Valid Operating Region
  - May differ for different data collection rates or background illumination conditions
- Characterize focus over Field of View as a function of optics temp, gimbal angle, etc.
- Determine response to extended radiance sources over the detector's dynamic range at nominal operating conditions
- Characterize effect of FPA temp on radiance calibration coefficients
- Characterize effect of FPA electronics temp on radiance calibration coefficients
- Characterize effect of bias voltage changes on radiance calibration coefficients
- Design of Experiment problem: Vary operational parameters together as indicated by empirical calibration model: Valid Operating Region

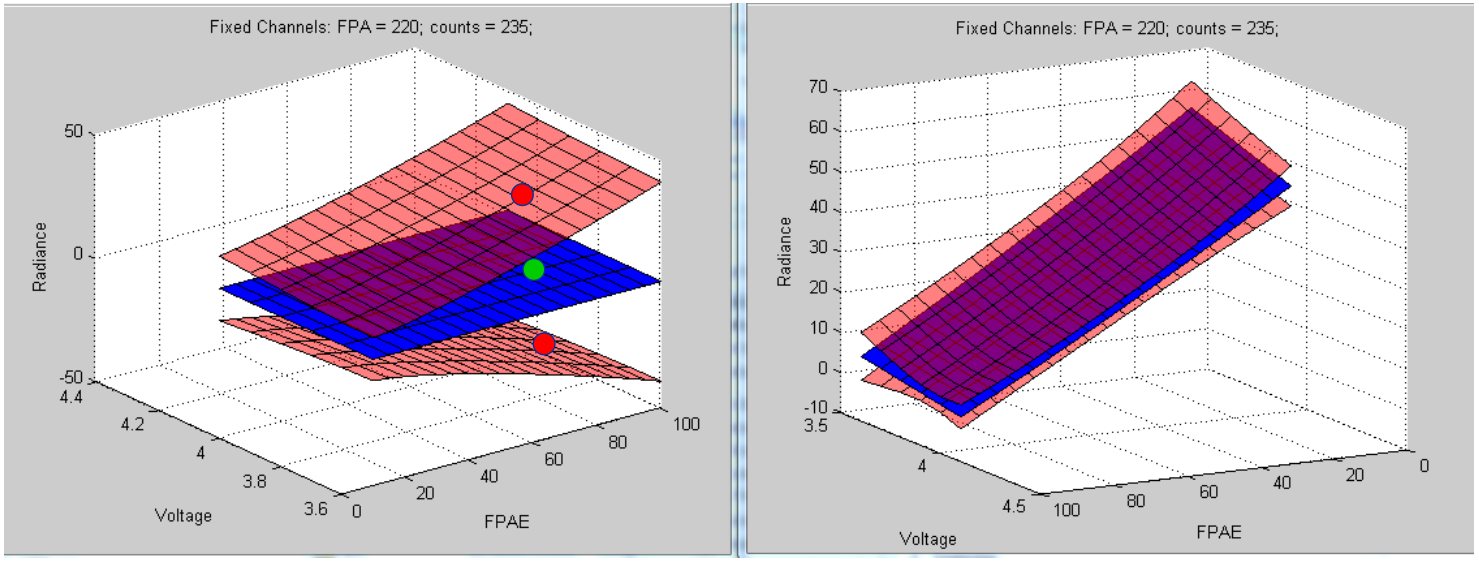
Calibration Model Building

- Flowcharts of decision logic for sensor calibration
- Covariance assessment is both a part of planning and execution



Apply Calibration Model

- Left is region of sensor operating parameter space where data is not well fit to the empirical model
- Right is region where data is well fit by the empirical model.



How do you act on this data?

What is the trigger to recalibrate?

Uncertainty bounds are known at calibrated points

Apply Calibration Model

- Calibration is performed per-pixel
- Uncertainty (1 standard deviation) computed per pixel
- Monitoring the uncertainty in real time
- Calibration is recomputed when an operational parameter (voltage, temperatures, …) varies by some threshold amount and the resulting calibration uncertainty bound is too high
- Otherwise, calibration continues to be applied to collected data

Benefits and Drawbacks over Traditional Calibration Processes

- **Drawbacks**
  - Large ground data collection required
  - Software tools that manages and guides the optimal data collection for the calibration model needs to be completed before ground test starts
  - Ground data collection method needs to be flexible to new direction from empirical calibration model
- **Benefits**
  - Sensor ultimately calibratable over a larger section of possible parameter space (temps, voltage, …)
  - Enables relaxation of operating parameter constraints chosen for calibration reasons, rather than sensor safe performance reasons
  - Efficient ground data collection and assessment of its completeness driven by empirical calibration model and management software
  - Calibrated data available as soon as sensor starts collecting mission data

Conclusions

- Systematic plan to define the calibration across the VOR
- Calibration approach is designed to cover both the case of a sensor in thermal equilibrium and of a sensor in transition
- Using these expanded ground test data collections, sensor data from early on-orbit or anomalous periods within the VOR can be calibrated
- Can be used alone or in conjunction with an on-board radiometric calibration source