The BASEL Methodology

Part 1-- Motivation

Geolocation Requirements & Challenges

Modern Geolocation Requirements for communications emitters present many unique challenges that are unlikely to be met with traditional methods originally developed for radar emitters:

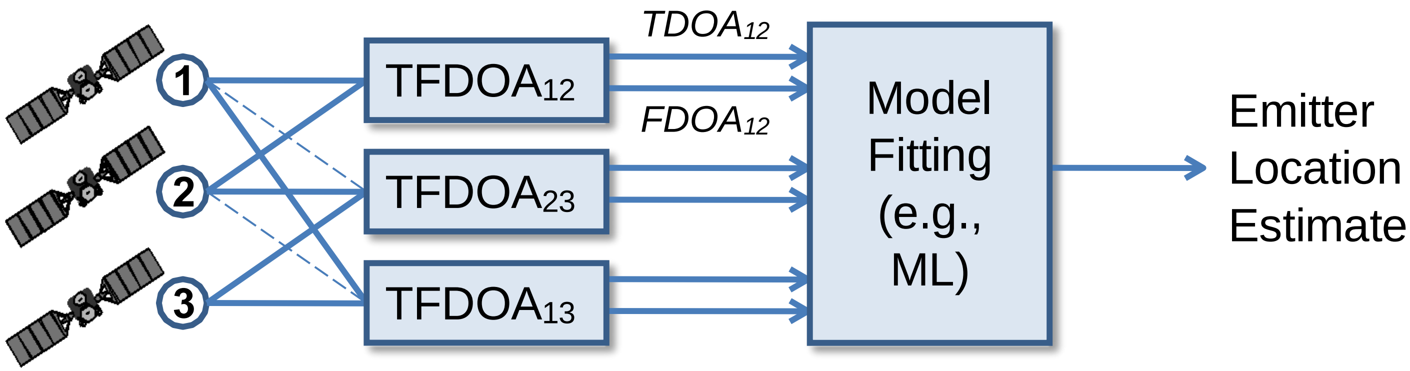
Key Geolocation Requirements:

- ✓ Accuracy
- ✓ Precision
- ✓ Sensitivity
- ✓ Selectivity
- ✓ Performance Prediction

Geolocation Challenges:

- Multipath Effects
- Blocked Line of Sight (LOS)
- Cochannel Interference (CCI)
- Low-Power Transmissions
- Short-Duration Transmissions
- Propagation Modeling
- Statistical Modeling of Collections
- Sensor & Emitter Motion
- Sensor Availability
- System Calibration and Modeling

Traditional vs Optimum Geolocation by TFDOA



This Traditional TDOA/FDOA (TFDOA) Method dates back to the earliest days of geolocation and remains the standard today; but it is not meeting today's requirements and challenges for communications emitters

To Replace the Traditional with the Optimum (Maximum-Likelihood):

Use all 3 sensors to estimate all 3 TDOA/FDOA pairs JOINTLY

Then, each of 6 estimates is aided by 5 others (instead of 1 other)

And all 6 (instead of 0) isochrones and isodops intersect at a UNIQUE point—the ML location estimate

Limitations of Traditional TDOA/FDOA

Traditional TFDOA-Based Geolocation is Sub-Optimum in general:

- Does not Estimate TFDOAs jointly using the Data from All Sensors
- Does not Model Multipath Reflectors as required to enable optimum mitigation
- Does not use all available Coherent Combining/Processing

Limitations of Traditional TFDOA Geolocation:

- Sensors w/o LOS to the emitter cannot be used for emitter location
- Multipath Ambiguities are inherent and often not removable
- Available Processing Gain & Sensitivity go unused
- Available Spatial Resolution & CCI discrimination go unused
- Accurate Performance Prediction is made more difficult

Optimum TFDOA-based Geolocation for CW has None of these Limitations

Limitations of Emerging Ad Hoc Techniques

Existing Long Coherent Integration TFDOA Techniques are sub-optimum but less so than traditional Non-Coherent Long Integration

Existing General-Search Geolocation Energy Mapping and other techniques that perform RF-Imaging are sub-optimum but less so than are Traditional TFDOA techniques.

These ad hoc techniques seem to have been motivated primarily by a desire to perform long coherent integration and resolve cochannel interfering signals – Not motivated by knowledge of what the Optimum Geolocation Method is.

Emerging Directed-Search techniques that provide signal-selectivity not available with General-Search techniques also are sub-optimum but less so than Traditional TFDOA techniques

These ad hoc techniques seem to have been motivated primarily by a desire to suppress cochannel interference – Not motivated by knowledge of what the Optimum Method is

Optimum RF-Imaging: The Path Forward

Optimum RF-Imaging Subsumes Existing Techniques (ETs)

- ETs for General-Search
- ETs for Directed-Search TOA/FOA Geolocation

Optimum RF-Imaging Enables Performance Improvement:

- By Enhancement of these ETs
- By Replacement of ETs with Optimum Techniques (Next Generation)

The new Paradigm of Optimum RF Imaging Provides:

- A Complete Mathematical Foundation and Algorithmic Framework
- Explicit Formulas for Performance Prediction

This will expedite the Paradigm Shift and the Development & Transitioning-Into-Operation of Revolutionary Technology for Geolocation of communications emitters

A Paradigm Shift in Geolocation

Bayesian Aperture Synthesis for Emitter Location (BASEL)

Part 2 – Programming Methodology

for the BASEL Processor

Proposed Paradigm Shift

Old Paradigm:

TFDOA-Based Location

New Paradigm:

Opt. Location by Imaging

Statistically Optimum RF-Imaging (BASEL)

Optimum RF-Imaging Directly Produces:

Optimum Emitter Coordinates (Lat/Lon/Alt)

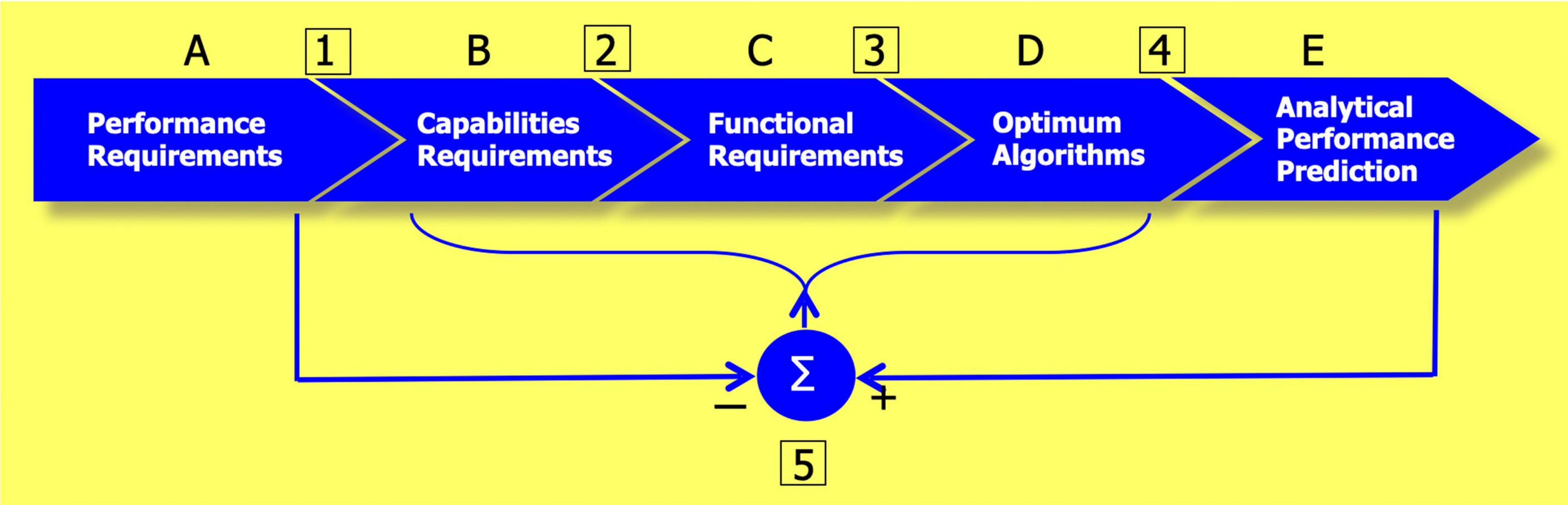
Jointly Optimum TDOAs/FDOAs can be calculated from Optimum Lat/Lon/Alt

Once the Optimum RF-Image has been produced, the Optimum Location is the Lat/Lon/Alt of the Dominant Peak in the RF-Image

TDOA/FDOA Estimates are not required, but may be used as a Means for Enhancing and Supporting Existing Sub-Optimum Geolocation Systems

Meeting Performance Requirements

5-Step Methodology for Programming the BASEL Processor
to Achieve Geolocator Design & Analysis



This entire *Optimum System-Design/Analysis Methodology* is

- Enabled
- Definitized

by *the BASEL Theory of Optimum RF-Imaging*

Meeting Performance Requirements — Step 1

Given a set of Performance Requirements (A), we specify a set of Required-Capability Options (B) that we wish to go forward with:

(**B**) Required-Capability Options
(*for mitigation of impairments*)

(**A**) Performance Requirements *(operations driven)*	CCI Suppression	Multipath Mitigation	Increased Spatial Resolution	Increased Noise Suppression	Blocked LOS Mitigation	Signal Selectivity / Ambiguity Resolution	Ionospheric Mitigation	Adaptive Calibration
Accuracy	•	•	•	•	•	•	•	•
Precision	•	•	•	•				
Sensitivity	•	•		•	•			
Selectivity	•					•		

Meeting Capability Requirements — Step 2

Having chosen a set of Capabilities Requirements (B), we specify a set of Required-Functionality Options (C) that we wish to go forward with

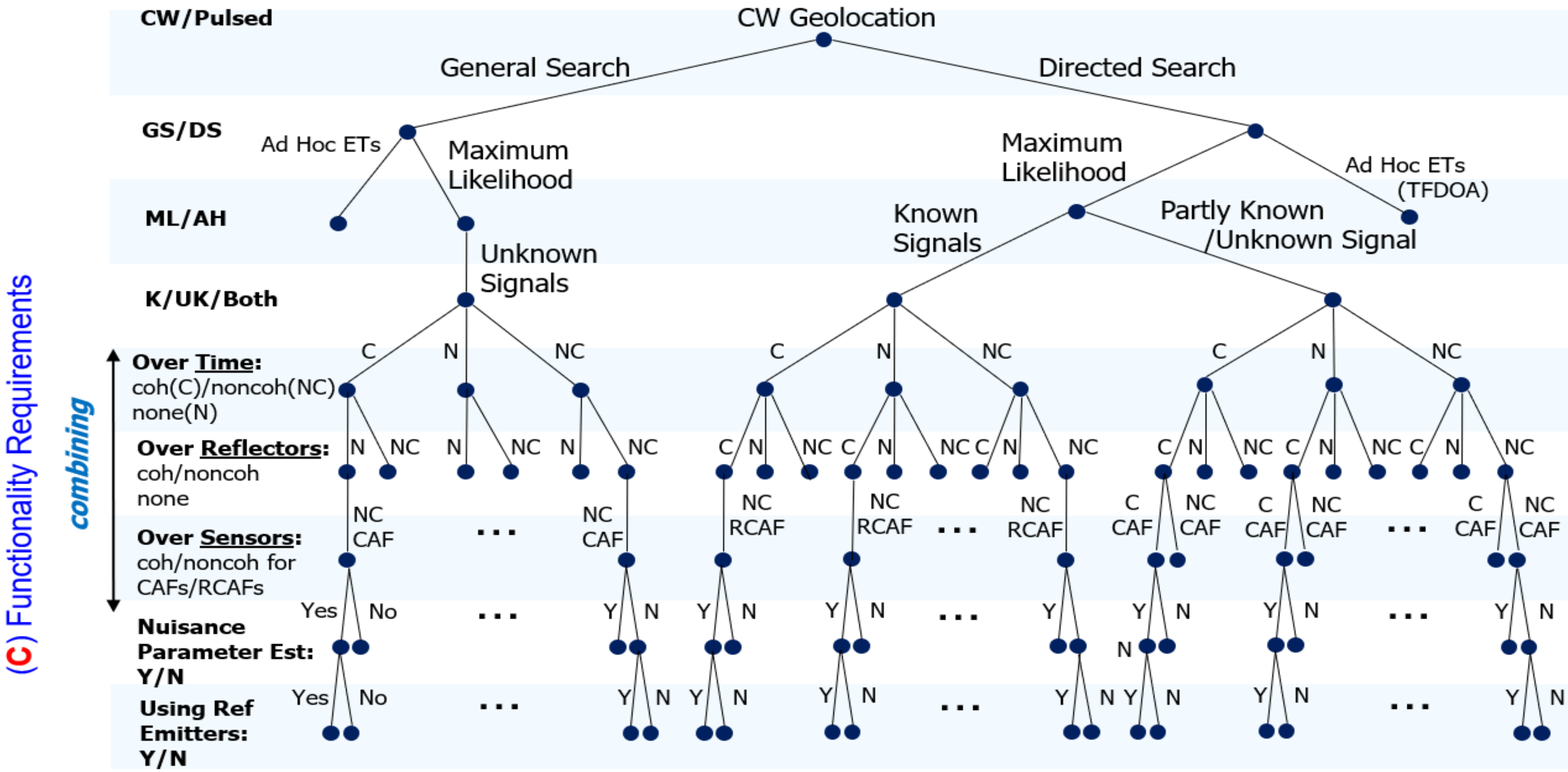
(B) Capability Requirements

(C) Functionality Requirements
(functionalities made available by optimum emitter location)

		CCI Suppression	Multipath Mitigation	Increased Spatial Resolution	Increased Noise Suppression	Blocked LOS Mitigation	Signal Selectivity / Ambiguity Resolution	Ionospheric Mitigation	Adaptive Calibration
Reference Signal Correlation (RCAF)		•			•		•		
Non-Coherent CAF Combining (NC-CAF)	OT			•	•				
	OS				•			•	•
	OR		•		•	•		•	•
Coherent CAF Combining (C-CAF)	OT			•	•				
Non-Coherent RCAF Combining	OT	•		•	•		•		•
	OS	•			•		•	•	•
	OR	•	•		•	•		•	•
Coherent RCAF Combining (C-RCAF)	OT	•		•	•		•		•
	OR	•	•		•	•		•	•
Non-Coherent CAF/RCAF Fusion		•	•		•		•	•	•
Coherent CAF/RCAF Fusion		•	•		•		•	•	•

Meeting Functionality Requirements — Step 3

Having chosen a set of functionalities (C), we specify a set of Required-Algorithm Options (D) by using the ML Decision Tree



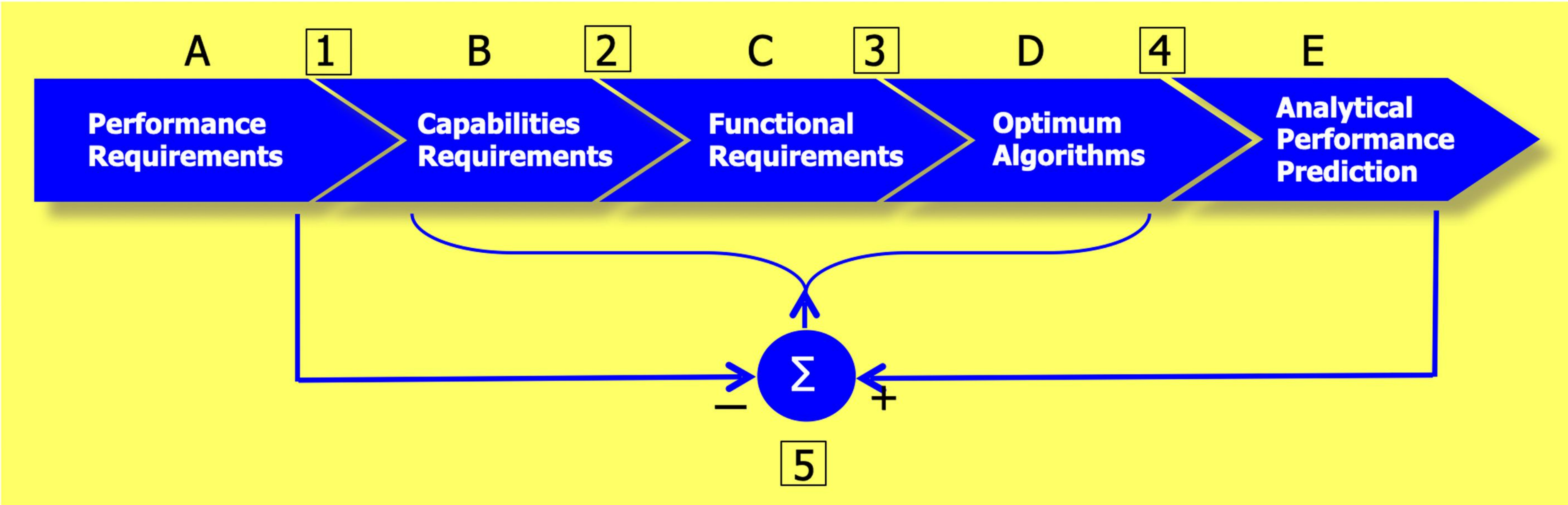
(D) Optimum (Maximum-Likelihood) RF-Imaging Algorithms

The Optimum Algorithms and Associated Performance-Prediction Formulas are
Explicitly Specified by the Theory and Ready for Software Development

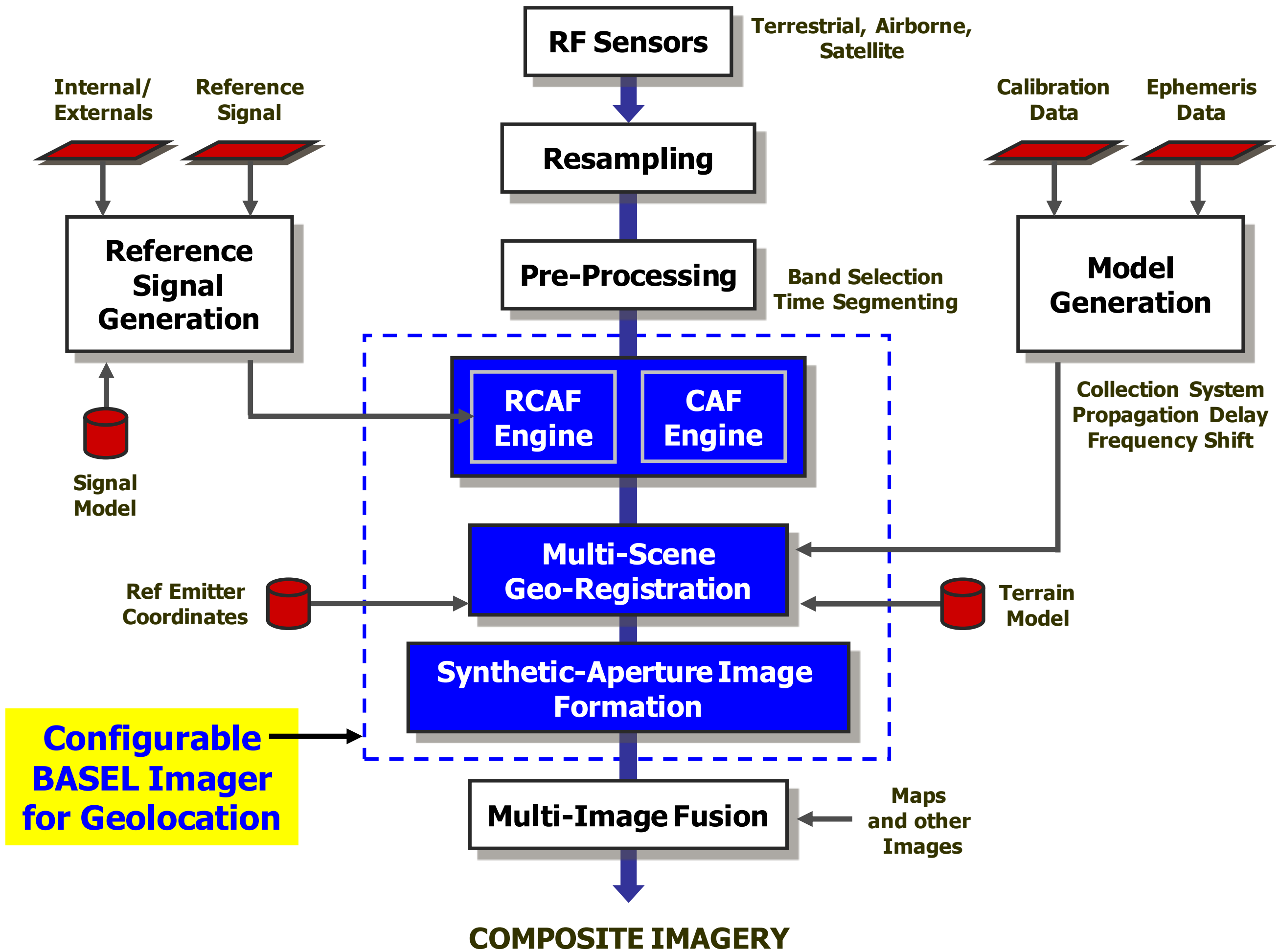
Predicting/Comparing Performance — Steps 4 & 5

Step 4 — Having selected the Required Algorithms (D), we select the corresponding Theoretical Performance-Prediction Formulas (E) and proceed to numerically evaluate performance

Step 5 — Having evaluated Predicted Performance (E), Compare with the Performance Requirements (A) and iterate through Steps 1, 2, 3, 4 as needed



Configurable BASEL Processor



BASEL Processor Configurations

From the *ML Design-Decision Tree* (Chart 12), we obtain a large set of Processor Configuration Options for the generic *Configurable BASEL Processor* (Chart 14), which are partitioned into Mode A and Mode B Configurations

- Mode A: SS-GEO (Signal-Selective Geolocation for Directed Search)
- Mode B: GS-GEO (General-Search Geolocation)

Each Mode contains numerous optional configurations that implement subsets of various capabilities, including

- Super Resolution of Multipath (SURGE)
- Location without line of sight
- Various data-adaptive self-calibration capabilities (system-parameter-error-correction)
- Various data-adaptive propagation-channel-modeling capabilities

Example Enhancements to Existing Techniques

Optimum RF-Imaging Theory Reveals:

- How to <u>Enhance</u> ETs for both General- and Directed-Search
- How to Design & Analyze <u>Optimum</u> Next-Gen RF-Imaging Techniques

Optimum RF-Imaging Algorithms <u>Enable</u>:

- Discrimination between Targeted and Interfering Signals detected by ETs
- Discrimination between Emitter and Reflector Locations produced by ETs
- Post Processing of ETs' detected reflector locations to Locate an Emitter that is Invisible to the ET because of Blocked LOS from ALL sensors
- Increasing ETs' Processing Gain and Sensitivity
- Implementation of the core raw-data processor using only existing CAF Engines that have been optimized through many years of development, Making <u>Multiple</u> Focused Re-Sampling per footprint <u>optional</u>