Computer Systems, Inc.
MERCURY

Real-Time Geo-Registration on High-Performance Computers

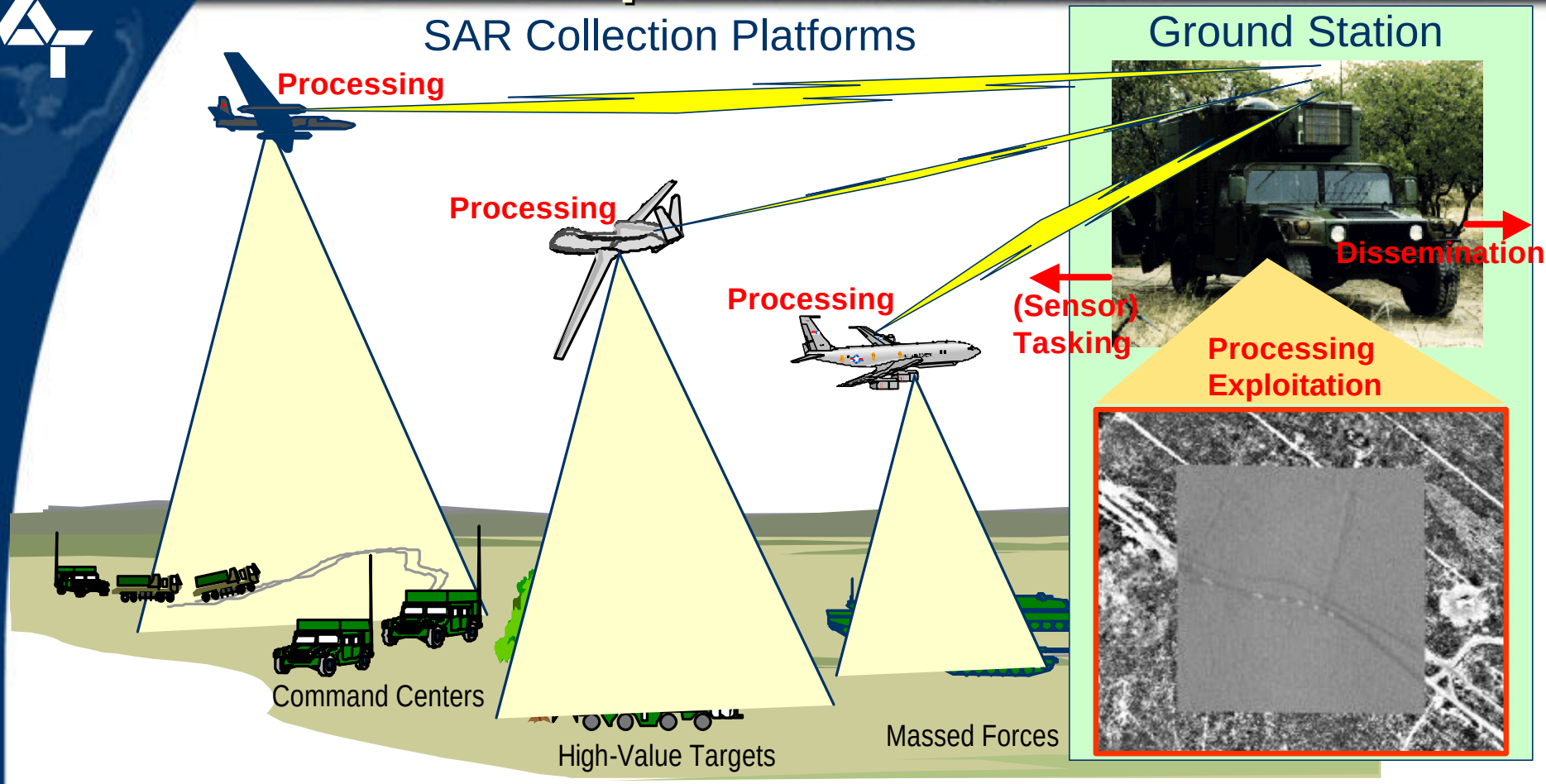
Alan Chao
Monica Burke
ALPHATECH, Inc.

Thomas Kurien
Luke Cico
Mercury Computer Systems, Inc.

High Performance Embedded Computing Workshop - September 24, 2002

The Ultimate Performance Machine

SAR Image Geo-Registration Desired Capabilities and Constraints



- Objective: prosecute time-critical targets in dynamic battlespace
- Requirement: near real-time mensuration and geo-location of targets in collected SAR image
- Satisfy space, weight, and power constraints (airborne sensor platforms, mobile ground stations)

Signal and Data Processing

- **Signal Processing**
  - MTI report generation
  - SAR image formation
  - Typically on collection platform
  - Requires 100s of GFLOPS
    - Function of input data rate
    - Data independent
  - Real time

- **Data Processing (Data Exploitation)**
  - Report processing
    - Registration
    - Target tracking
    - Multisensor report fusion
  - Image processing
    - Image-level (geo-registration, mosaicking)
    - Chip-level (ATR)
  - Typically on ground station
  - Requires 10 to 100 GFLOPS
    - Function of input data rate
    - Data dependent
    - Need to formulate multiple interpretations of data (perform search)
  - Non-real time ➡ Real time

Target Chips: regions (from full image) containing potential targets

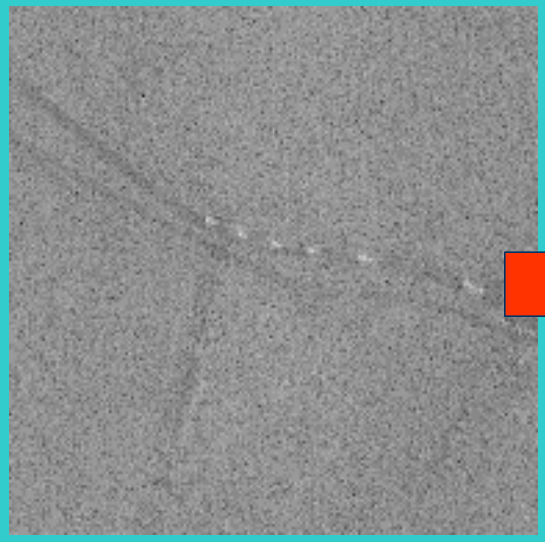
Image Geo-Registration

- **Objective: determine spatial correspondence between collected image and geo-referenced data**

Geo-Referenced Image

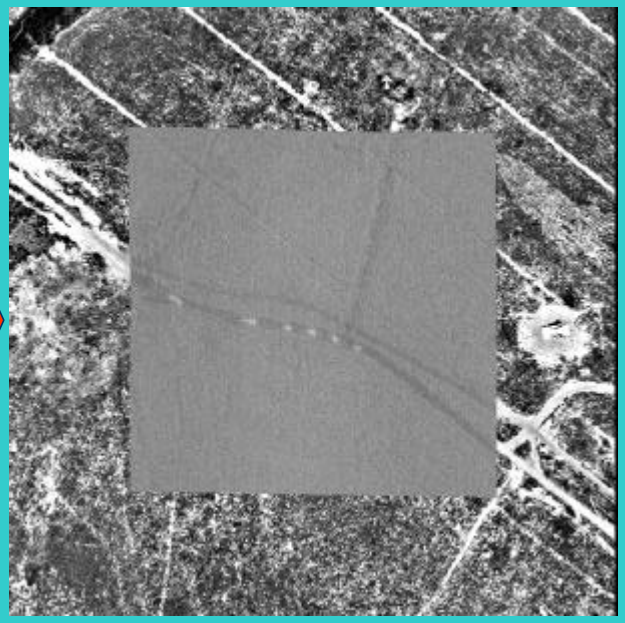
(Ortho-Photo)

Collected Image



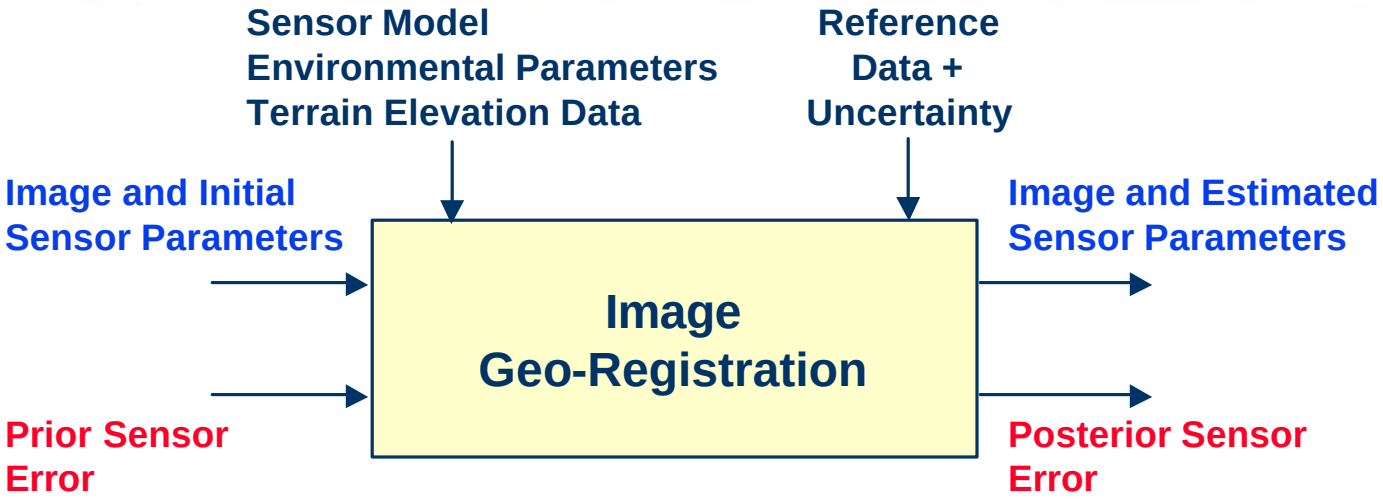
(SAR)

Geo-Registered Image



- **Image geo-registration prerequisite for:**
  - **Target mensuration and geo-location**
  - **Change detection**
  - **Fusion of geometric/spectral information across images**

Image Geo-Registration Approach



- **Registration estimates the most probable location of an image relative to a reference.**
- **Two coupled sub-problems:**
  - **Feature selection and association:** extracting salient features across data and computing the optimal correspondence between the two sets of features for a given set of image collection parameters.
  - **Collection parameter estimation:** computing the optimal image collection parameters for a given correspondence between the two sets of features.

Search Problem

Throughput Requirements

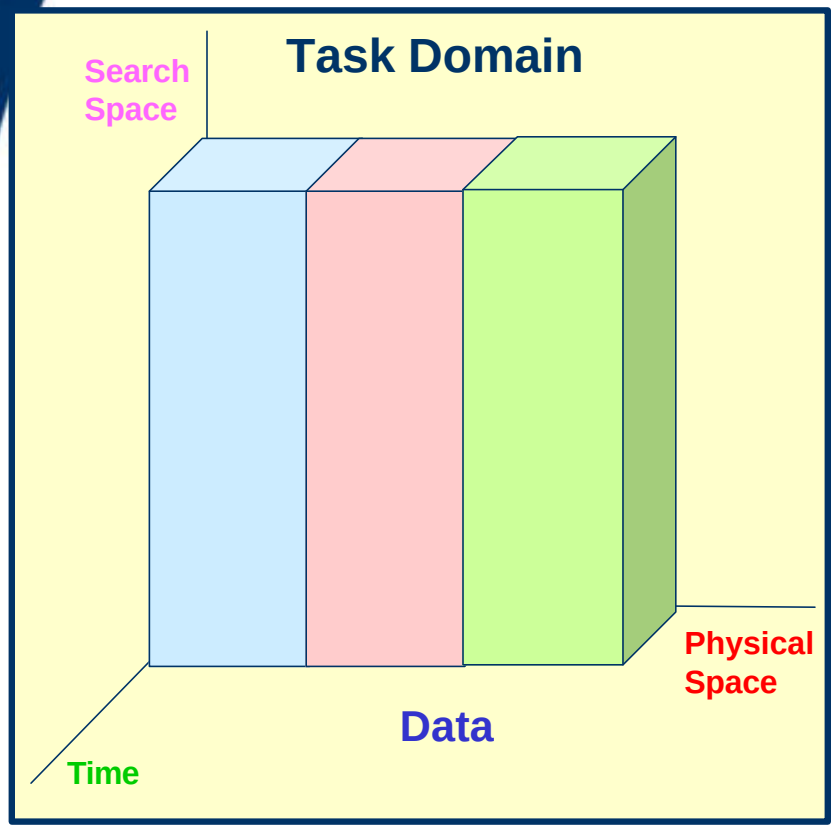
- Function of
  - Feature- or intensity-based approach
  - Features used (e.g., topological, region, object)
  - Matching algorithm (e.g., Hausdorff distance, Bayesian metric)
  - Desired accuracy
- Preliminary Estimates
  - Intensity-based algorithm for SAR image registration
  - 1800 x 1800 pixel SAR image
  - ~60 Giga operations
  - High throughput driven by high-input rate and requirements for search
  - Need multiprocessor implementation

Mapping Approach

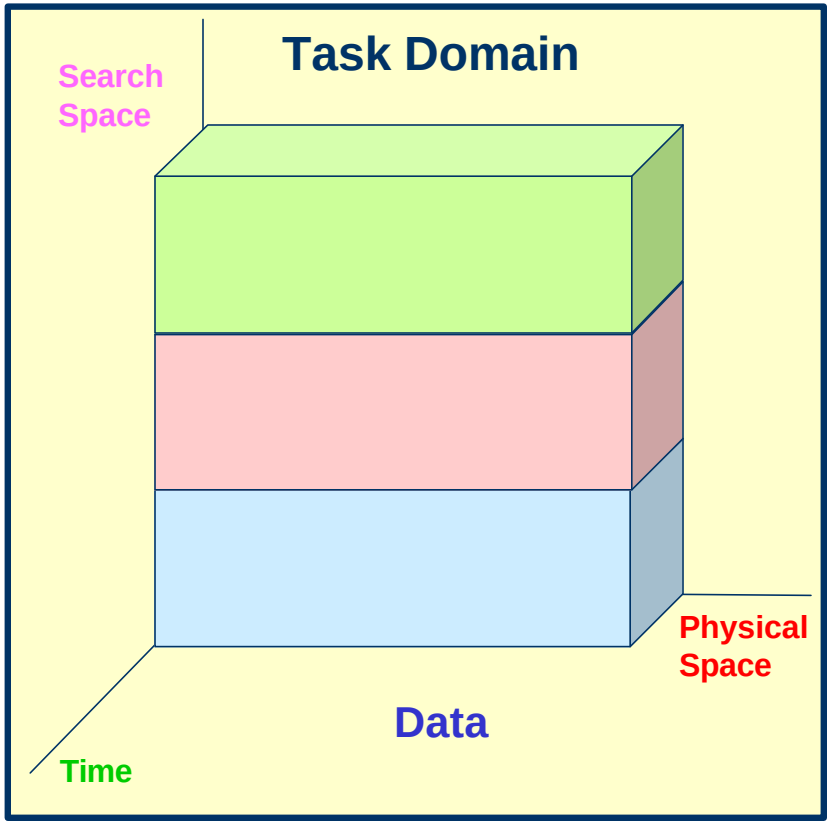
- General Techniques
  - Round-robin scheduling (process replication)
  - Pipeline processing (process partitioning)
  - Data parallel processing (process replication with partitioned data)
- Data Parallel Processing Applicable for Data Exploitation Algorithms
  - Partition data sets in either search or physical space
  - Select partitions requiring high throughput
  - Minimize processing latency by distributing parallel tasks over multiple processors
- Mapping of Image Registration Algorithm
  - Evaluation of match metric is compute-intensive
  - Match metric computation can be performed in parallel

Data Parallel Tasks

- Data Exploitation Algorithms
  - Contain data-parallel tasks in both physical and search space



Data Partitions in Physical Space (e.g., MHT, ATR)

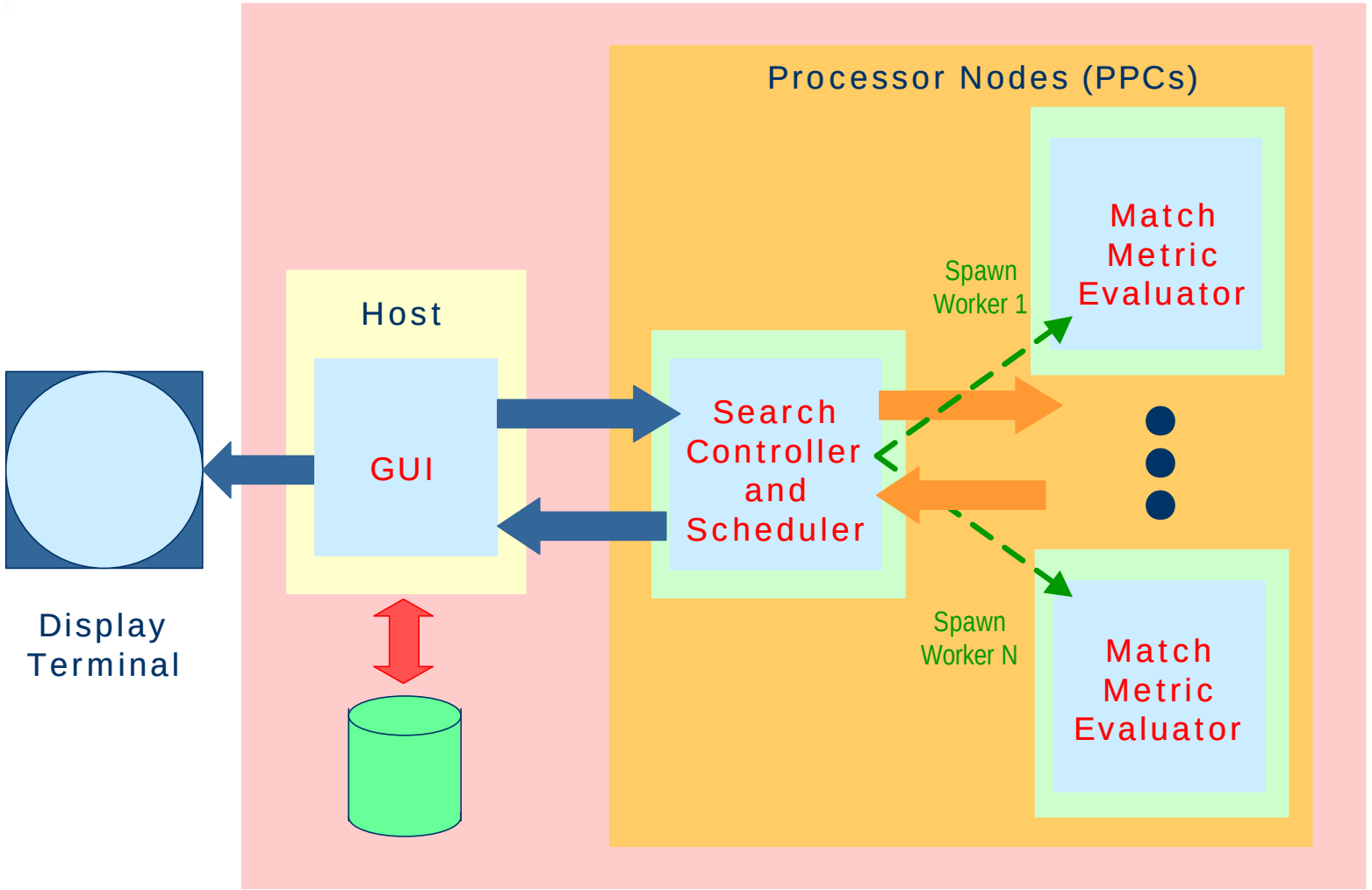


Data Partitions in Search Space (e.g., Registration)

Geo-Registration Implementation

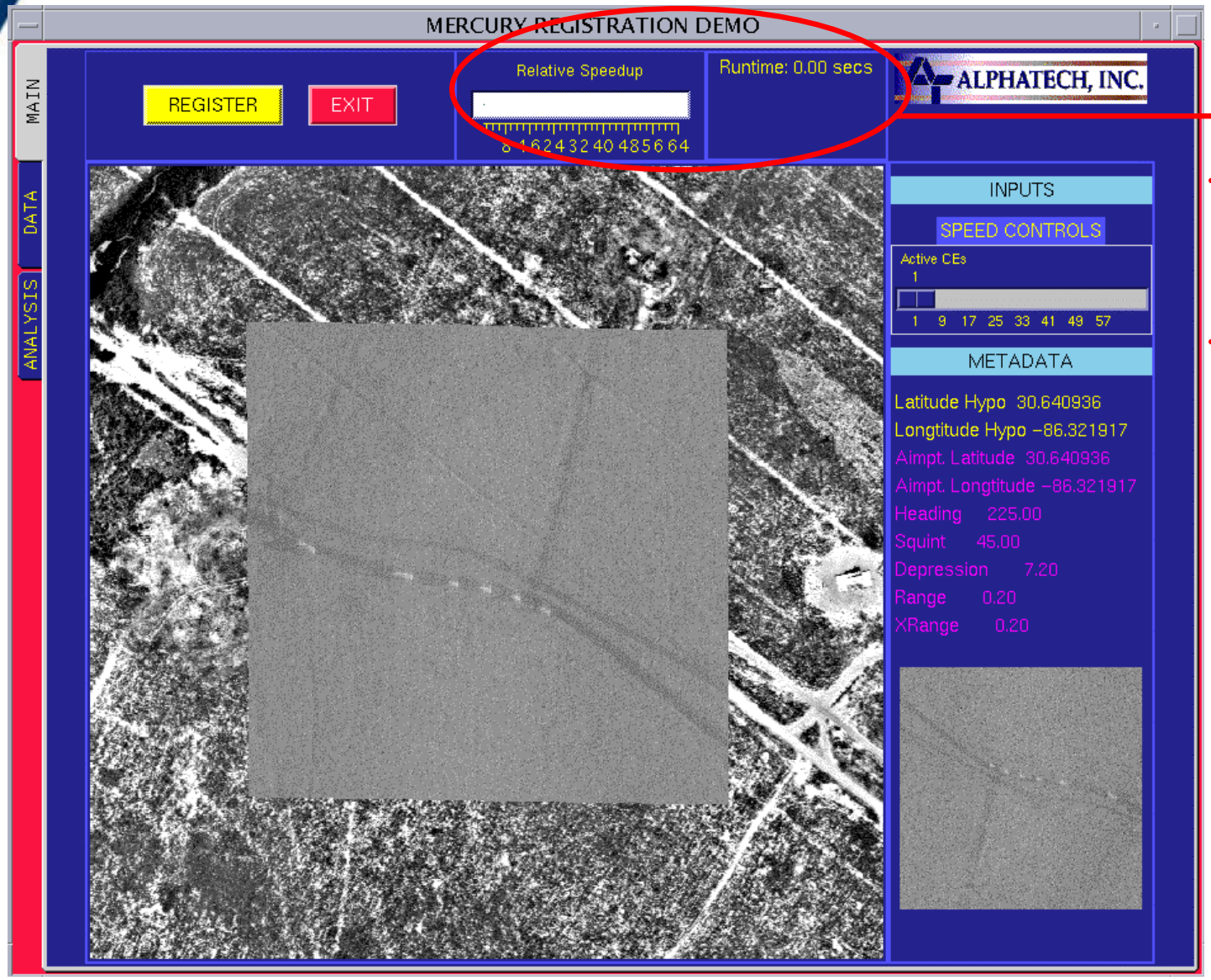
- **Hardware: Mercury VME System**
  - 1 host board containing host processor (GUI + I/O)
  - 2 6U boards containing 8 PowerPC processors (geo-registration algorithm)
  - RACEway Interconnect (ILK-4)
- **Software**
  - Tcl/Tk (GUI)
  - C++ (geo-registration algorithm)
- **Middleware**
  - Efficient distribution of data and tasks to multiple processors, synchronization tools (currently using MPI; plan to use PAS™)
  - Efficient implementation of standard scientific and image processing functions on PowerPC (plan to use SAL and Pixl™)

Geo-Registration Implementation on Mercury System



Match Metric Evaluator: Mutual Information in Pixel Intensity Distributions

Scalable Geo-Registration Algorithm: Demo Interface



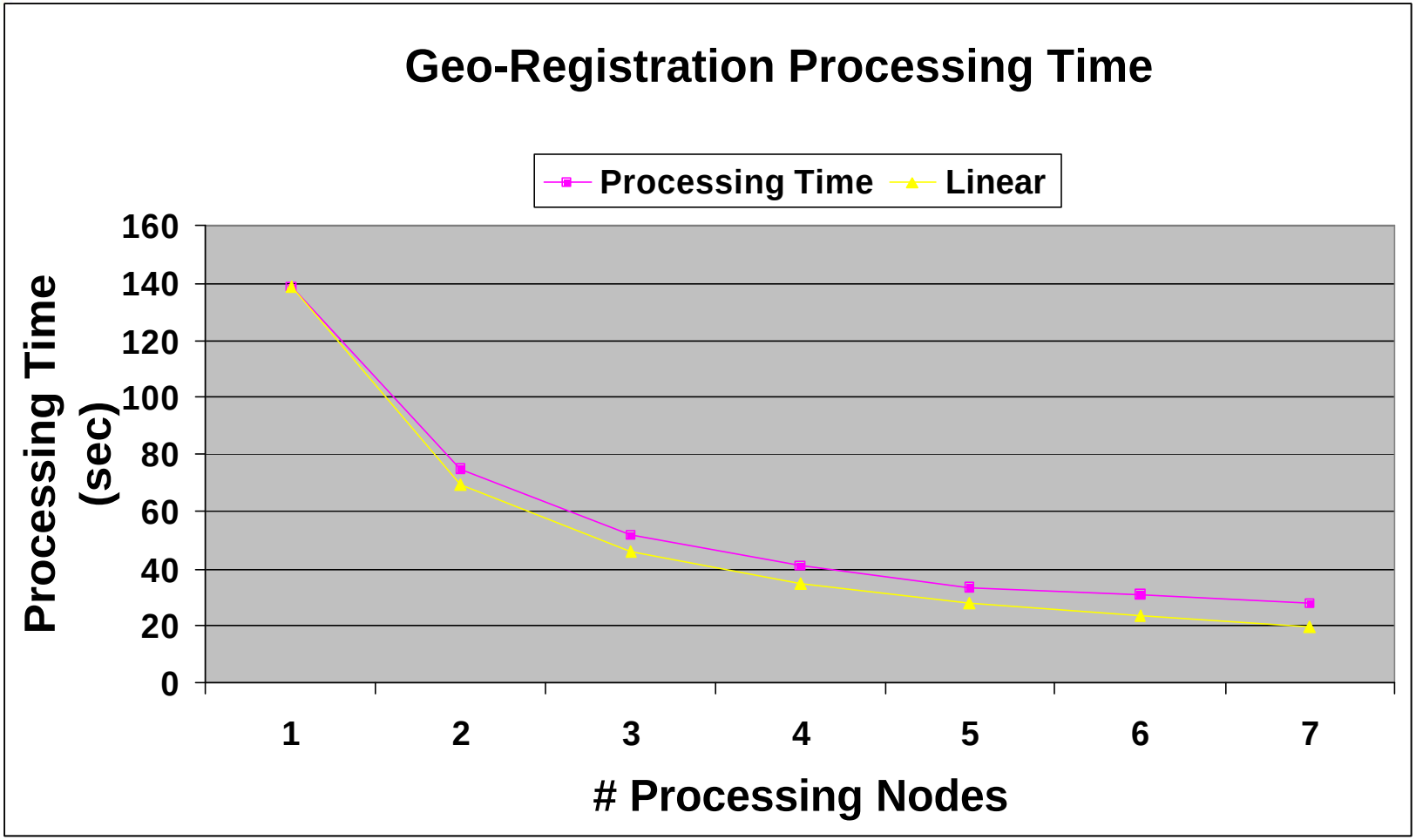
Scalability Results

Number of Processors

Test Image Metadata

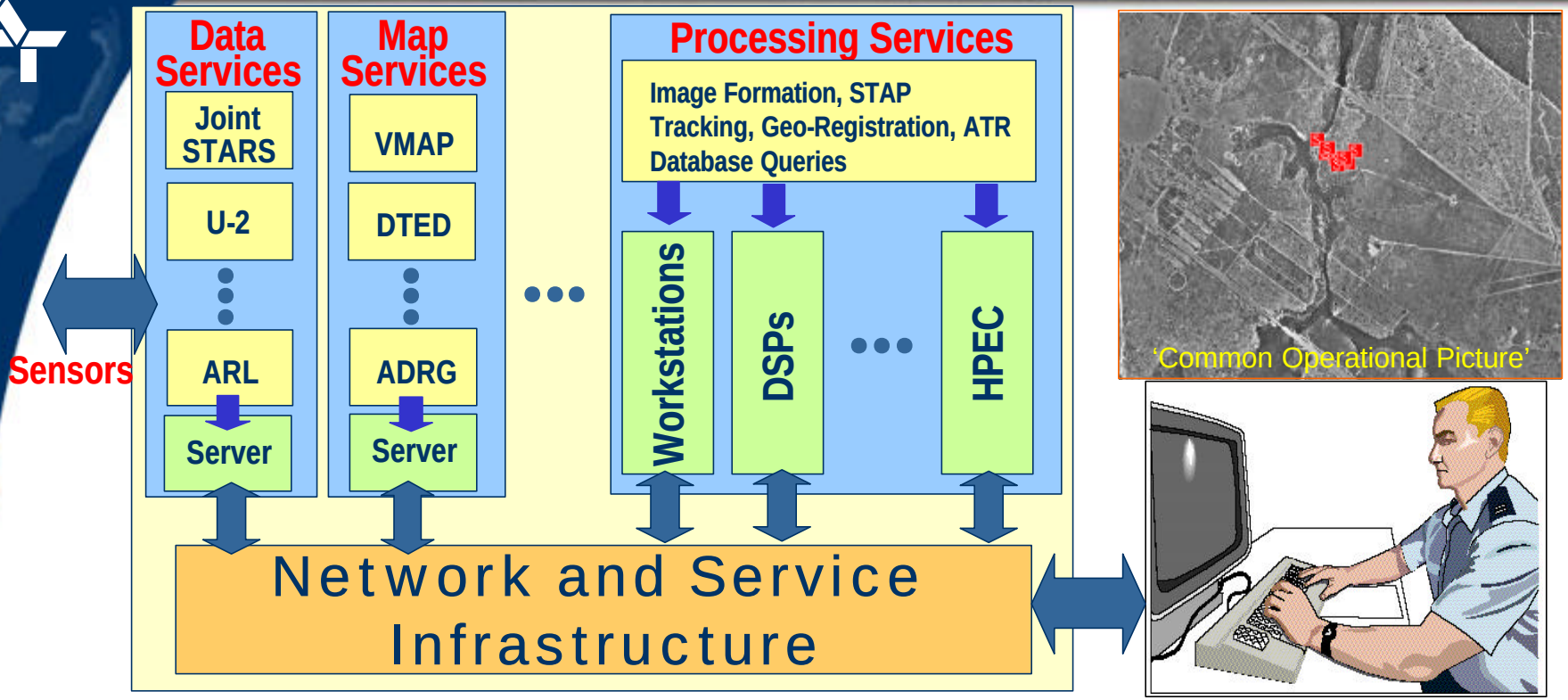
Test Image

Computational Scalability



- Implementation demonstrates close to linear scalability
- For 64-processor system: ~ 2.2 seconds (estimated)

Network-Centric, Service-Oriented Architecture for ISR Systems



- **Role of High-Performance Embedded Computers**
  - Provide multiple ISR processing services (STAP, Tracker, ATR, etc.)
  - Parallel algorithms enable the surveillance operator to specify desired QoS for each service
- **Mercury/ALPHATECH Developing Scalable High-Performance Data Exploitation Algorithms for ISR Systems**