Migrating a Representative U.S. Naval Combat Systems Application to Real-Time Java

Tim Childress
Barbara Doyal

Naval Surface Warfare Center
Dahlgren Division

The OA Surface Application Domain

- **Large distributed real-time weapon system applications**
- **Both soft and hard real-time applications**
- **Timescale for deadlines typically in the O(10) – O(100) millisecond range**
- **Long system life spans, often for several decades**
- **Consequences of not meeting requirements for time-deterministic behavior could be severe**

Established Surface Domain OA Computing Environment (OACE)

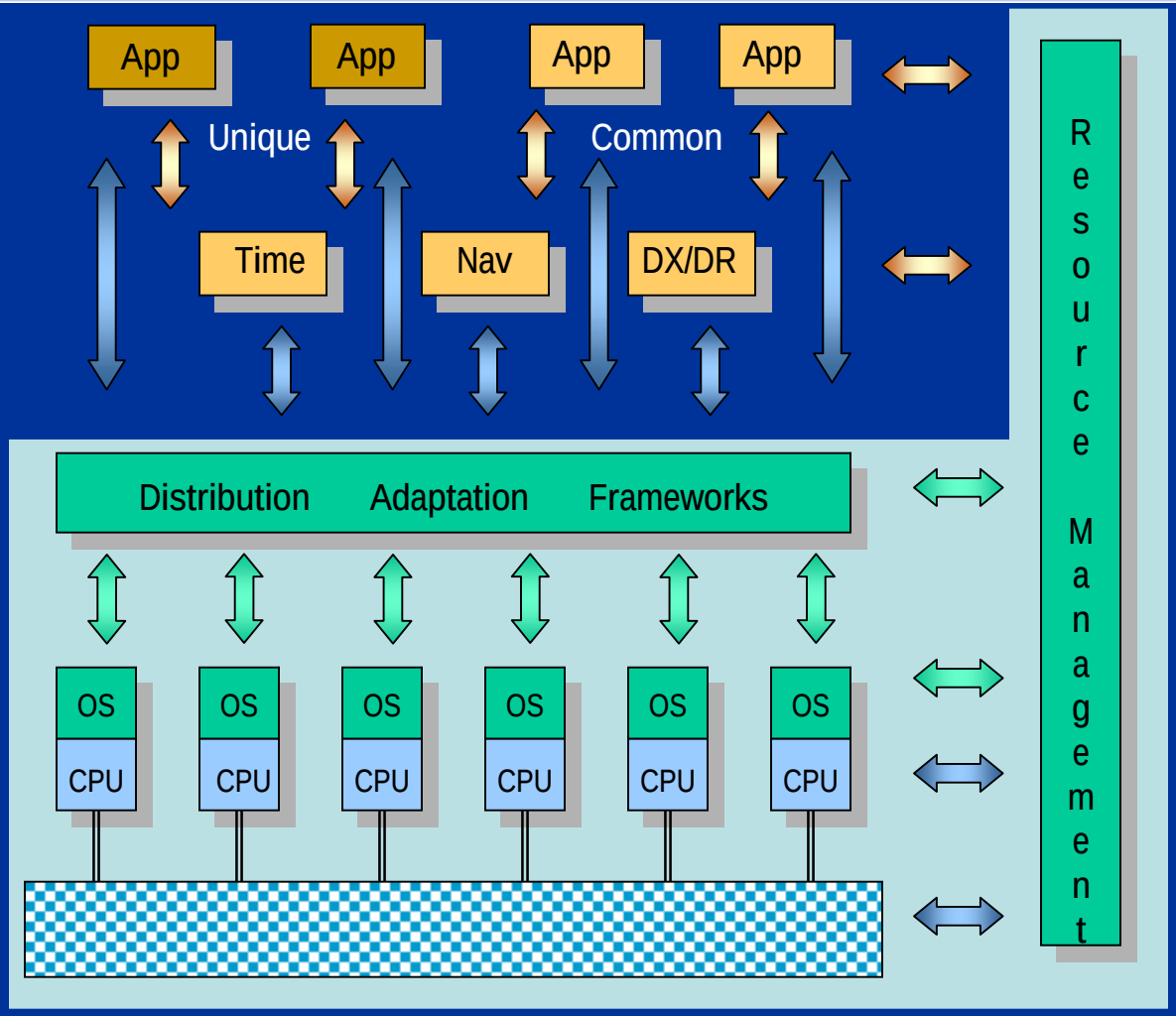
Domain Unique
- Warfighting Applications
- &
- Common Services

Open Architecture Computing Environment (OACE)
- Standards Based
- Commercial mainstream

Standards Based
- Middleware (OMG)
- Operating Systems (IEEE POSIX)

Developer Choice
- Mainstream COTS Processors

Standards Based
- Cable Plant & Layer 3 Switched / Routed LAN (TIA, IETF)



Standards and Middleware Isolate Applications From Technology Change

The Dilemma of Java for OACE

- **Java, one of the two programming languages approved for new development in U.S. Navy surface domain Open Architecture applications, offers considerable advantages for software development**
  - Designed from ground up to be object-oriented
  - Automatic memory management reduces debugging time
  - Rich API set encourages programmer productivity
  - Java applications are portable
  - Large base of Java developers and third-party Java products
- **But standard Java is not conducive to real-time programming**
  - Automatic garbage collection can cause apps to pause at any time
  - No mechanism to prevent priority inversion
  - No facilities for asynchronous transfer of control, safe asynchronous thread termination, or direct access to physical memory

Java Technologies for Real-Time

- **Standard Java**
  - May suffice for some real-time applications if usage of features that impact determinism is severely restricted
- **Standard Java with Real-Time Garbage Collection**
  - IBM J9 JVM with Metronome garbage collector
- **The Real-Time Specification for Java (RTSJ)**
  - Sun Mackinac, AICAS Jamaica
  - RTSJ and real-time garbage collection are not mutually exclusive
- **“Java-Like” Virtual Machines with Real-Time GC**
  - Aonix PERC

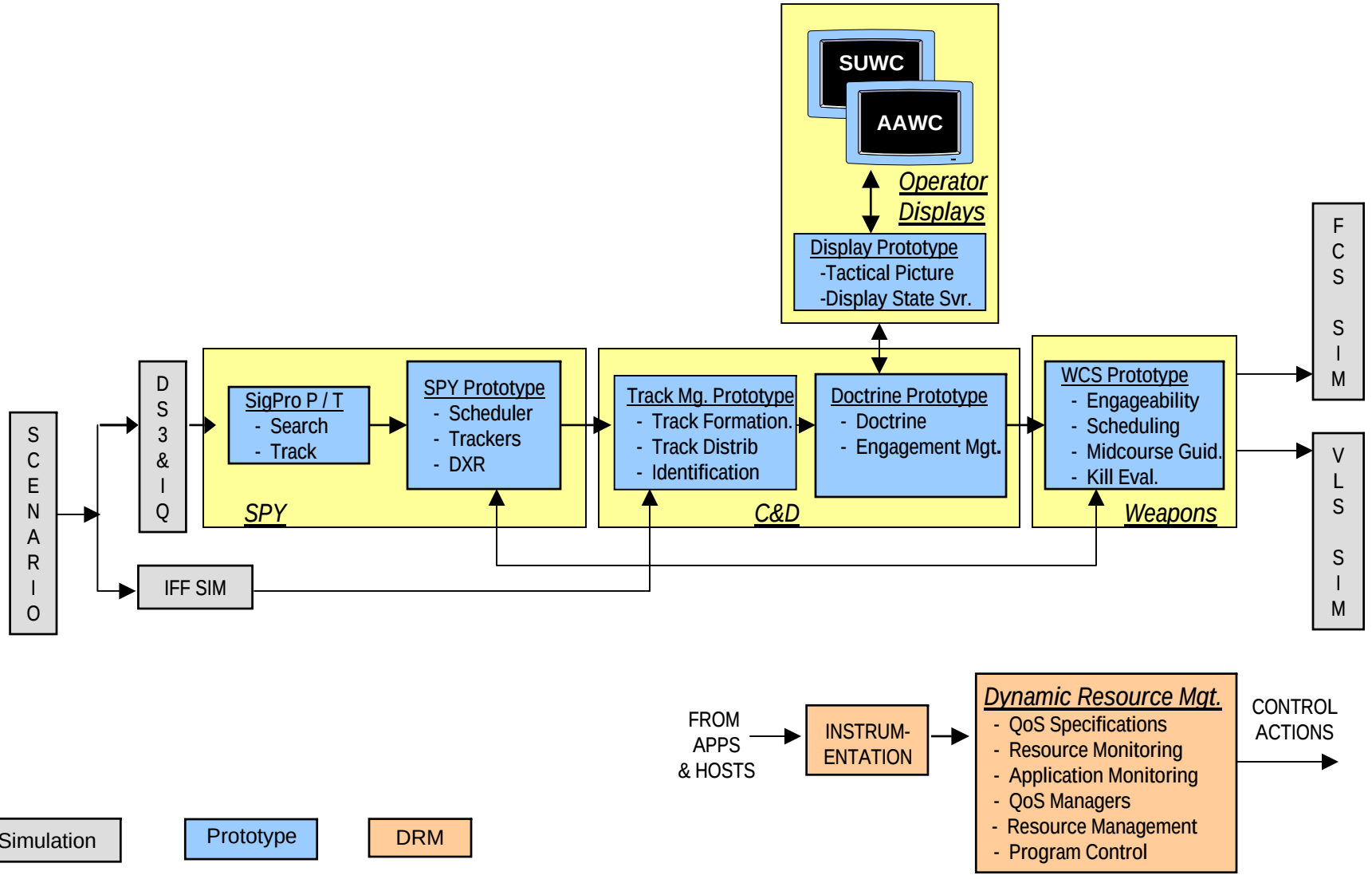
Objectives of this Investigation

- **Obtain information on which technologies, and which subsets of features within them, are appropriate for different regions of the real-time application space**
  - For example: Is there a class of soft real-time applications for which real-time garbage collection is sufficient, without having to use RTSJ-specific features (even if using an RTSJ JVM)?
- **Gain insight on appropriate techniques and design patterns for application of real-time Java technology in the OA domain**
  - Languages typically provide many alternative ways to implement solutions, but which are best suited to the problems we encounter?
- **Identify possible deficiencies in existing real-time Java technologies for our domain of applications**
  - Such knowledge could be applied toward the development of a Mission-Critical Java

Metrics of Interest

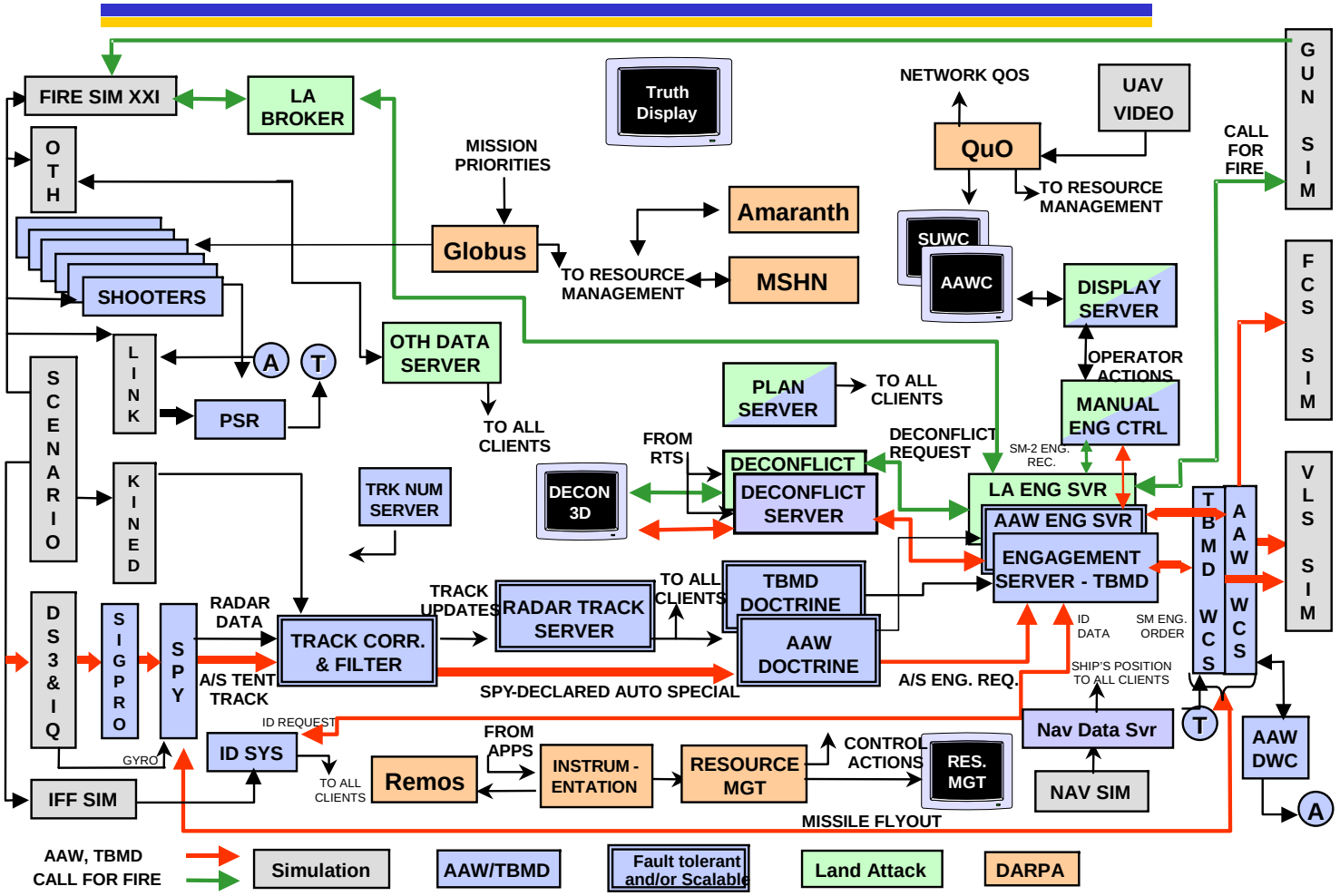
- **Timeliness**
  - Degree to which application meets real-time deadlines
- **Jitter**
  - Lower jitter means more consistent real-time behavior and consequently more predictability
- **Resource usage**
  - Memory, CPU utilization, etc., as a function of time
- **Load**
  - Application behavior under heavy processing scenarios
- **Relevant characteristics associated with application development:**
  - Portability
  - Maintainability
  - Scalability
  - Ease of development

Aegis-based OA Prototype

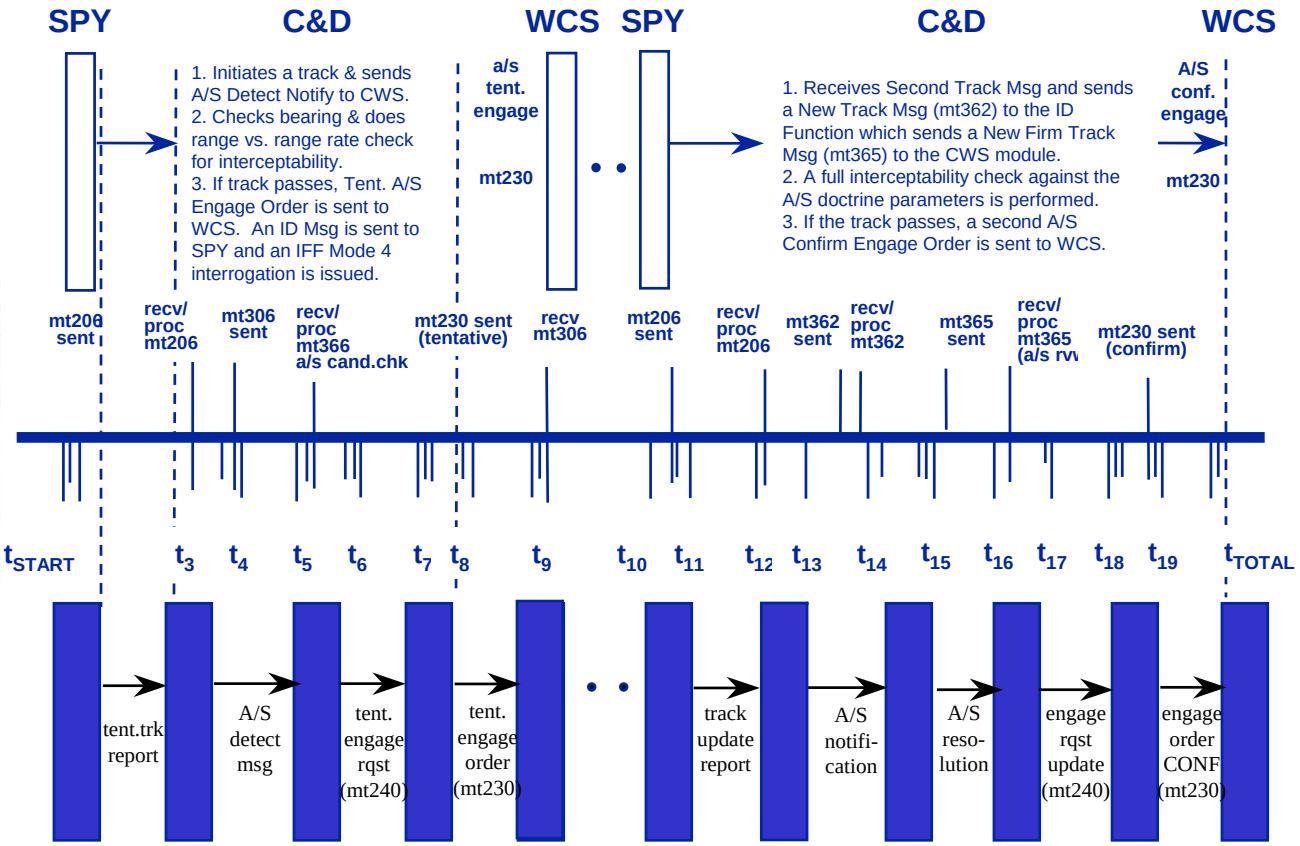


Auto-Special in Context

Demo 01 Block Diagram



Aegis Auto Special Timeline Example



“Real-Time” implies meeting the auto special reaction time requirement from detection to deployment of missile, following a deterministic critical path mission

Auto-Special Migration Phases

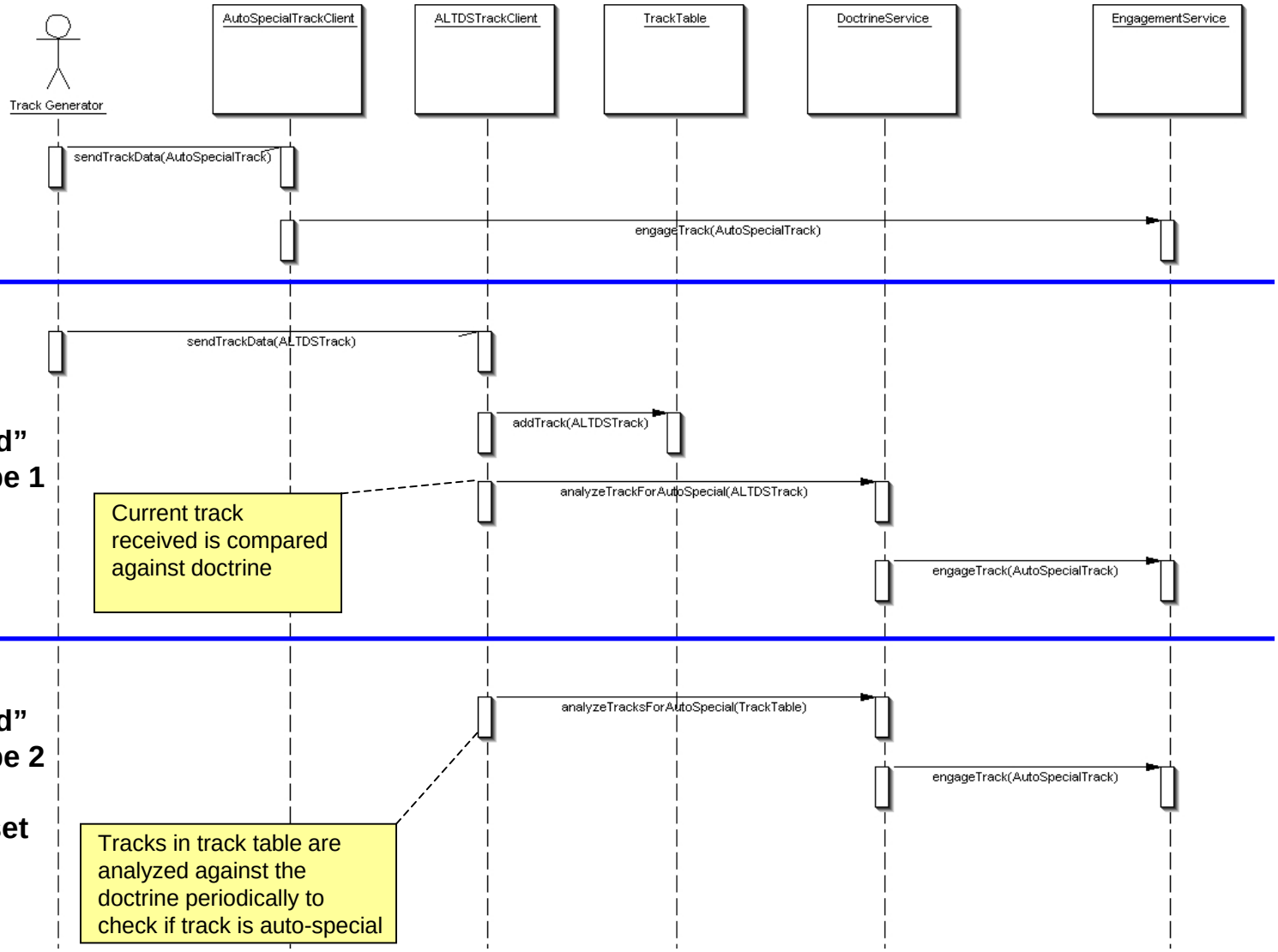
- **Phase 1: Analyze Existing Application**
  - Analyze existing C/C++ A-S code, using both automated and manual analysis techniques
  - Develop support environment, e.g., track generator
- **Phase 2: Port to Standard Java**
  - Translate existing application design into Java, with only minor refactoring from original design
  - Collect metrics of interest to compare with C/C++ version
- **Phase 3: Refactor**
  - Refactor Java code base to utilize both standard and real-time design patterns
  - Collect metrics for JVMs (both standard and RTSJ) with real-time garbage collection
- **Phase 4: Create RTSJ Version**
  - Modify design to leverage RTSJ-specific features
  - Collect metrics for RTSJ solution

Auto-Special Scenarios

1. **"Spy Declared" Auto-Special**

2. **"C&D-Determined" Auto-Special Type 1**

3. **"C&D-Determined" Auto-Special Type 2 (Analysis of all track files on a set interval)**



Current Status and Plans

- **Current Status**
  - Analysis of existing application complete
  - Design of initial Java implementation complete
  - Skeleton of initial Java implementation is complete; currently filling in application logic
  - Design and development of track generator in progress
  - Examining RT Java technologies for proper insertion into migrated Auto-Special application
- **Plans for Subsequent Work**
  - Summarize and report findings
  - Extend migration to include additional areas of the Aegis-based U.S. Navy OA prototype
  - Evaluate real-time middleware products in Java environment
  - Provide results and experience as input to the OACE document update process