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System Engineering and Integration for Submarine Combat Systems in the COTS Environment

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Submarine Combat System Paradigm Shift

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- Submarine combat systems employ Commercial-Off-The-Shelf technology and open system standards to provide:
  - An affordable path to leverage commercial technology in parallel with the build-test-build development cycle
  - Asynchronous rapid transition of advanced functional improvements through modular software builds in a networked environment
- Harnessing this capability required a change to the system engineering, interface, integration, and configuration management processes

This SE&I Model Was Proven Successful on the Virginia Class Combat System

Today's Dynamic Environment

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- Varying acquisition "cycle times" between subsystems
- Fleet driven rapid introduction of warfighting capability
- Technology transition from custom to COTS
- Radical reductions and gaps in funding
- Spiral Development
- Increasing system complexity
- Software Intensive Systems
- Desire for commonality across platforms
- Network Centric / Interoperability
- Information Security and Assurance

Business Models have evolved to adapt to the changing environment

Architecture Contrast

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Closed System

- Use of closely held, private interfaces, languages, data formats and protocols
- Critical importance given to unique design and implementation
- Use of individual company preferences to set and maintain interface specifications
- Vendor and technology dependence
- Difficult and more costly integration
- Use of sole-source vendor
- Expansion and upgrading usually requires considerable time, money and effort
- Components, interfaces, standards, and implementations are selected sequentially

Open System

- Use of publicly available and widely used interfaces, languages, data formats and protocols
- Critical importance is given to interface management and widely used conventions
- Use of group consensus process to maintain interface specifications
- Vendor and technology independence
- Easier and more cost effective to integrate
- Use of multiple vendors
- Easier, quicker and less expensive to upgrade
- Components, interfaces, standards, and implementations are selected interactively

Interface Management is the Key to Success

Source: ITEA Journal: September/October 2001 (Volume 22, Number 3)

Open System Model

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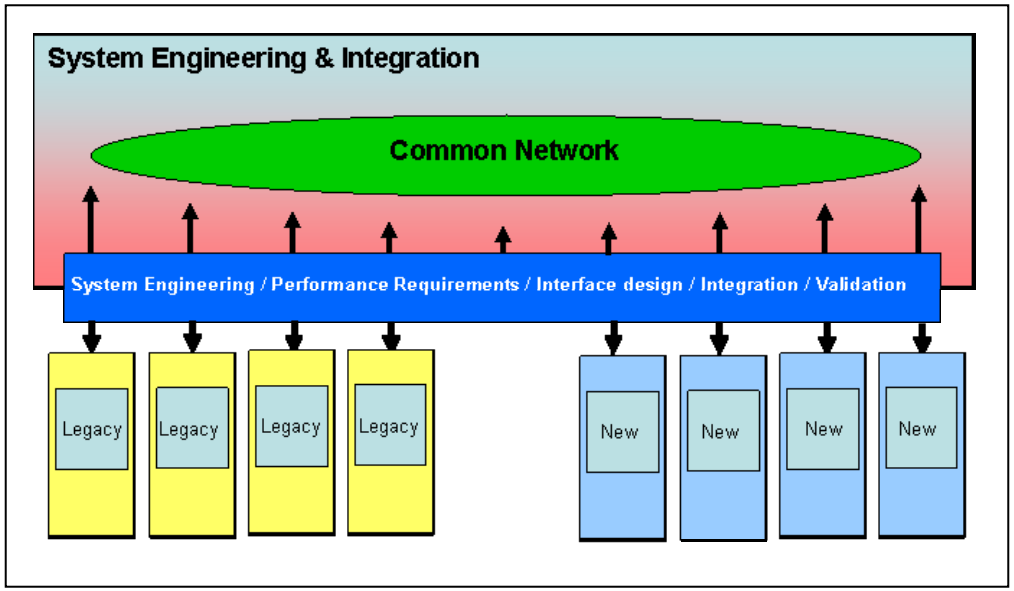
- Focus on the network and subsystem to subsystem domains to define and manage:
  - Open Architecture / Open System Standards
  - Interface Design and Definition
    - Functional not physical
  - Network Design, Services and system performance
  - Network software solutions
  - Technology Evolution
  - Standardized processes and products



This Open System Model has been implemented on the Submarine Functional Interface Baselines by a disciplined and measured approach to interface development and data flow management

Virginia Class Submarine Combat System

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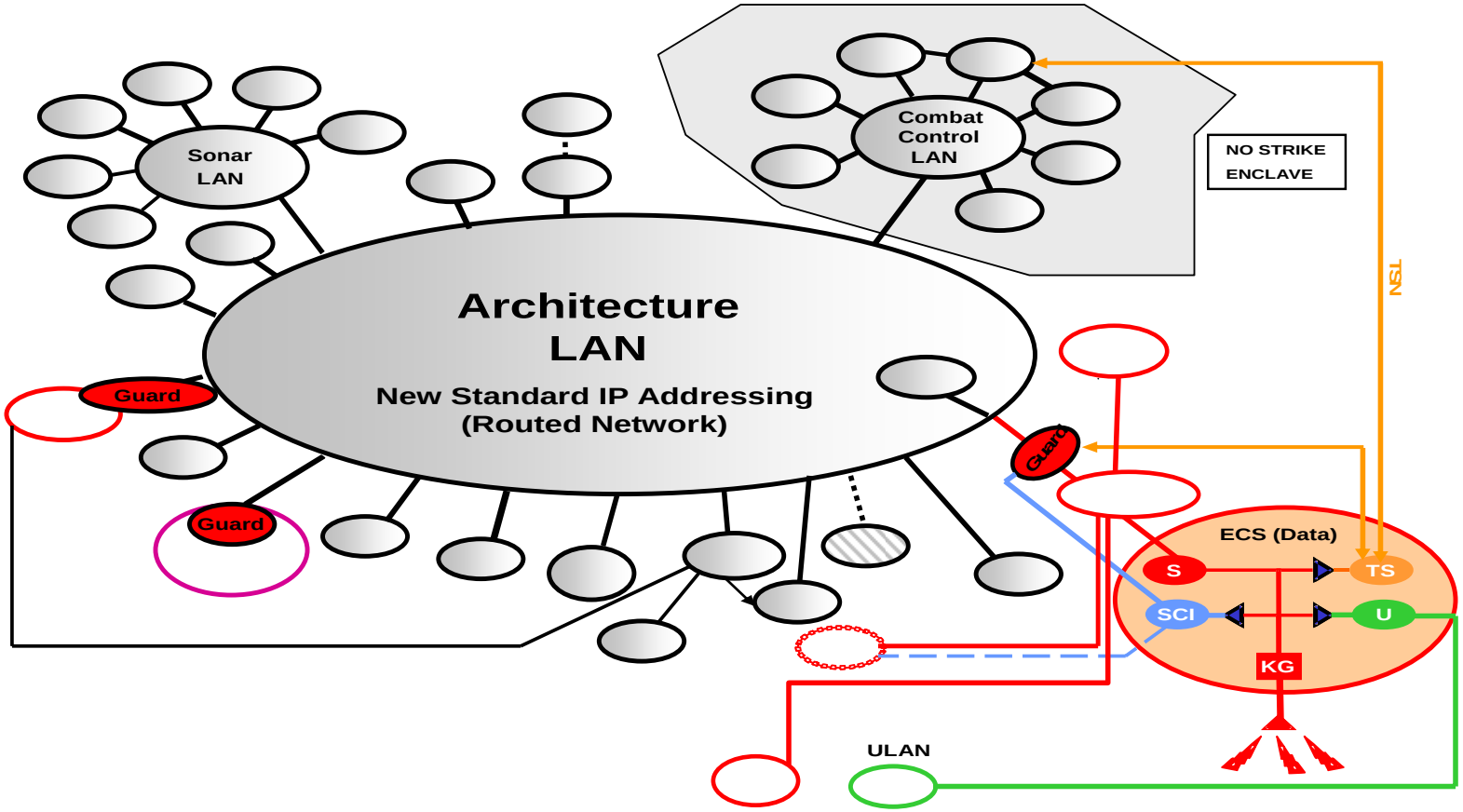

Need to manage and control the interfaces for the 23 subsystems of the Virginia Class Submarine Combat System

It Starts with Requirements Management

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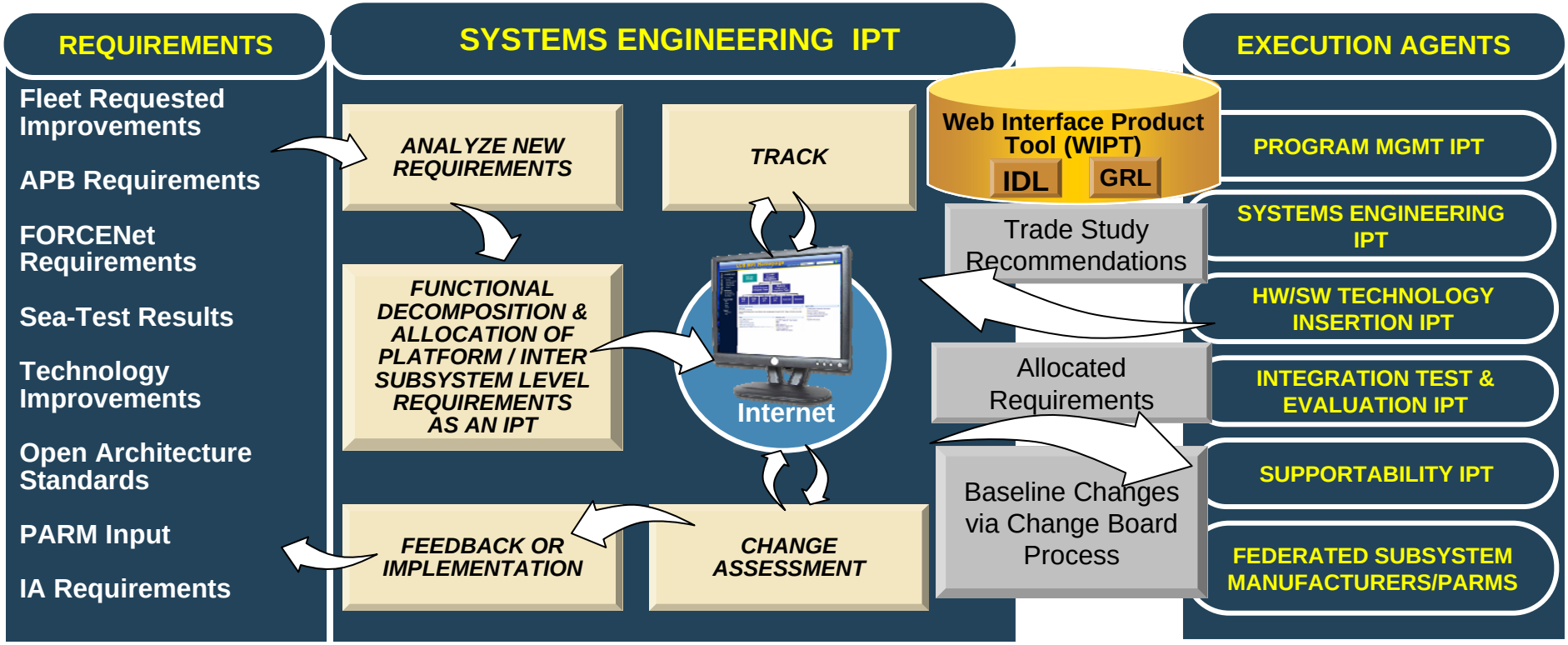
SE&I provides Top Level Combat System and Interface requirements. All other requirements are managed by the Federated subsystems



A Streamlined System Engineering Approach

Evolution of Interface Standardization

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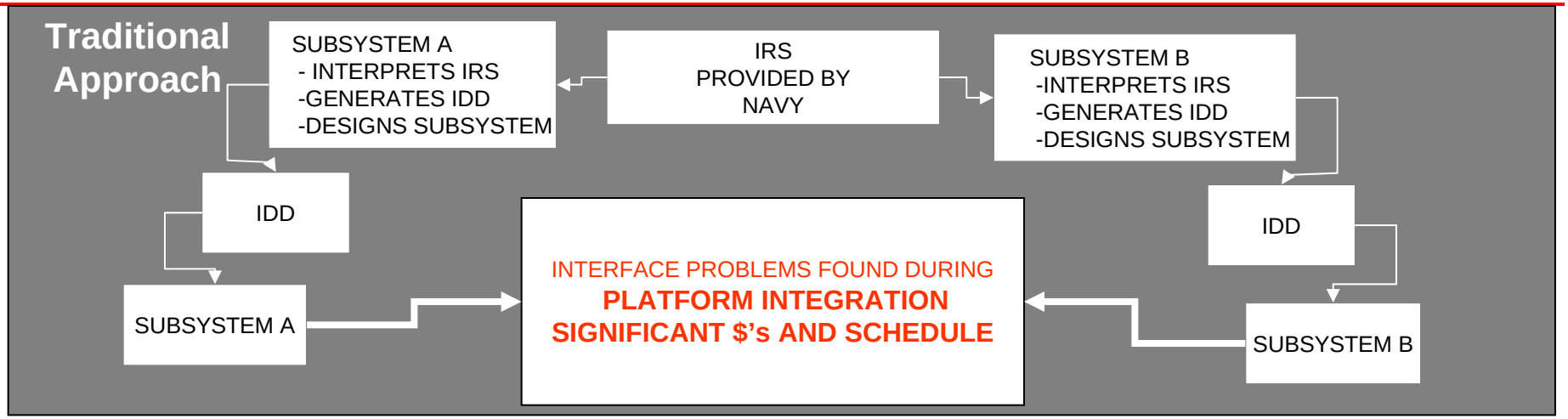

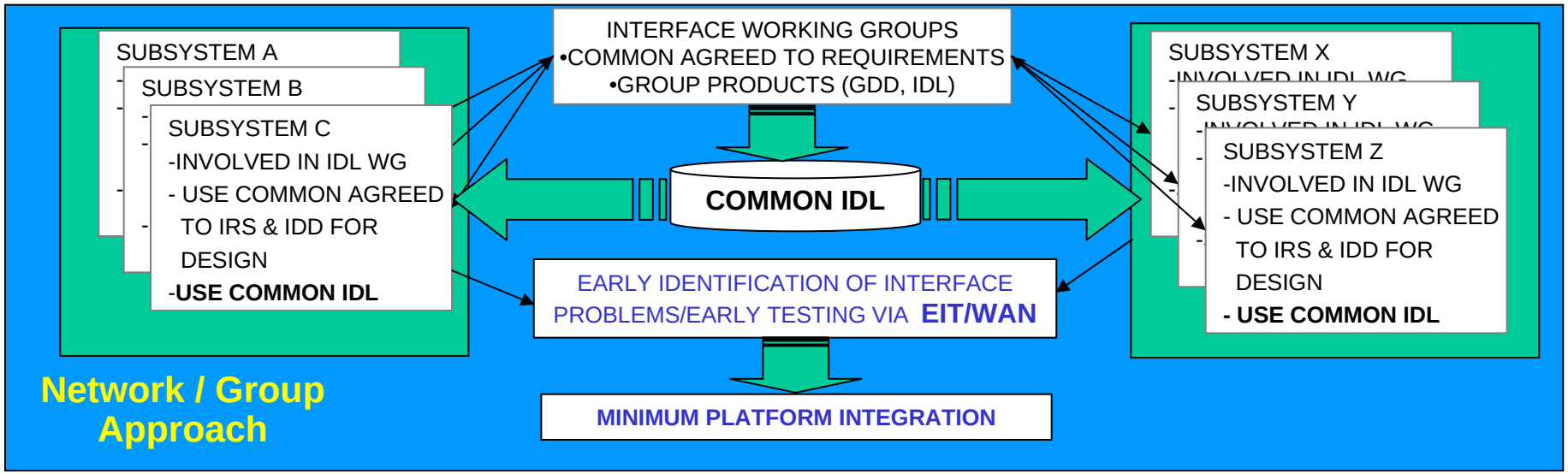

System Engineering
Network Architecture, Interface Design

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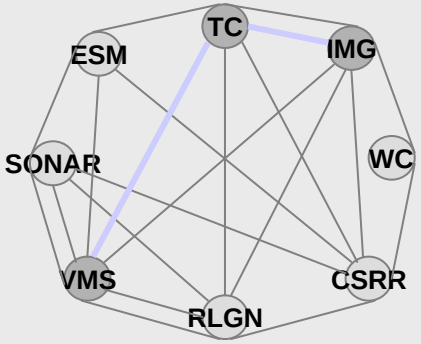
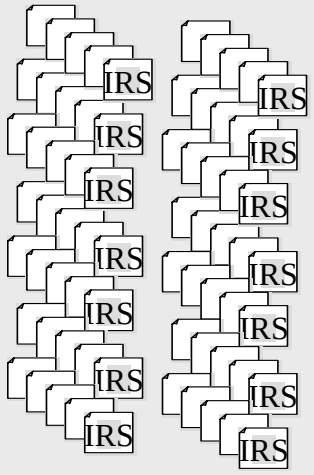
Yesterday

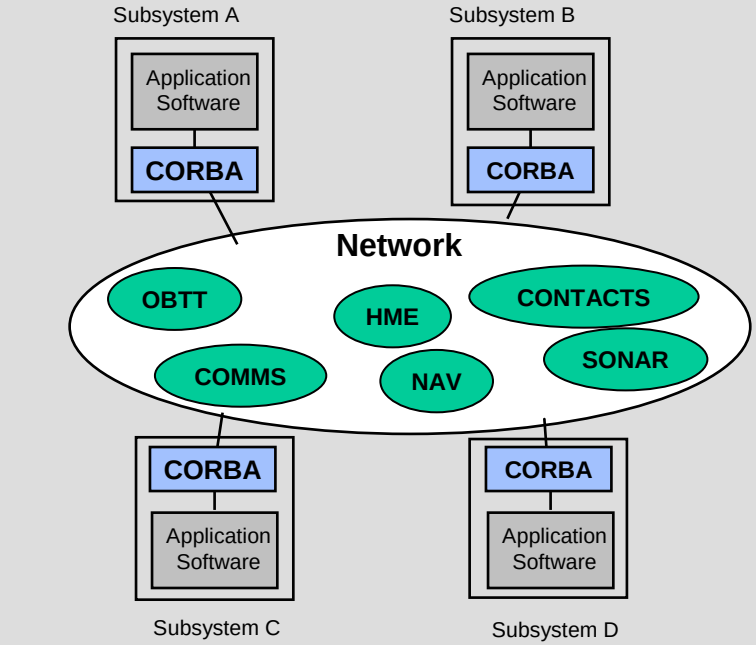
Traditional Point to point Design Process

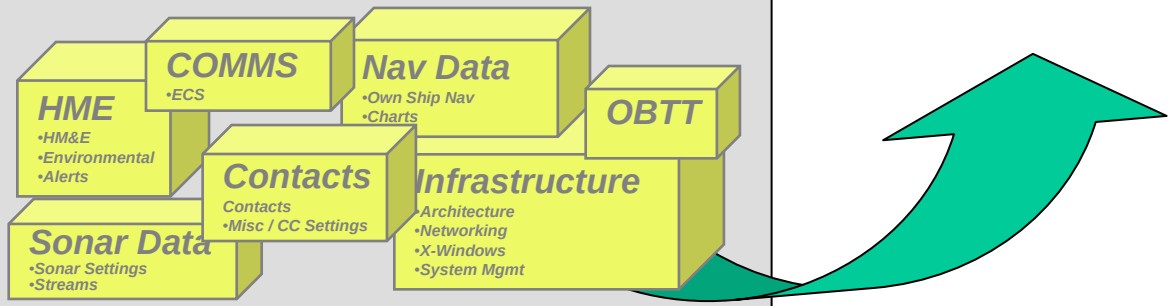




Today

Network / Group Product Design Process





Interface Working Groups

Group Products

- Open System Architecture Requirements and Standards (OSA)
- Group Requirements List (GRL)
- Interface Definition Language (IDL)
- Group Data Dictionary (GDD)
- System Network Design

SE&I Interface Product Definitions

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- **SE&I Interface Products under Configuration Management:**
  - **Group Requirements List (GRL)**
    - Database that contains all interface requirements for all subsystems.
  - **Group Data Dictionary (GDD)**
    - Contains definitions for all Interface Data Elements (IDEs) and IDE Assemblies (IDEAs) produced and consumed by subsystems within a Data Group
  - **Interface Definition Language (IDL)**
    - IDL provides the standard interface between objects, and is the base mechanism for object interaction between subsystems.
  - **Interface Integration Data Base (IIDB)**
    - Provides details of what interfaces are required for each subsystem on a per hull basis. Grouped by interface types and contains the Interface / method / Name Space Name (CORBA), Service Name (Services), Subsystems, GRL linkages, GDD linkages and indications of Provider, Recipient, Originator.

SE&I Product Relationships

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Request For Subsystem Requirement Change/Enhancement

Facilitators develop requirements and products based on request

GRL

Data Group	GRL Sequence Number	Role	Requirement	PP:ACINT	PP:ARCH	PP:ASDS	PP:CC	PP:CKTD	PP:DSVL	PP:ECS:NDP	PP:ESM	PP:IA	PP:Imaging	PP:LMDS
Contact	12800	O	The Sensor Report Event provider shall support a 1 Hertz rate for sending Events. This means, that the Sensor Report Event provider can generate Events and will have them in the queue for sending out, on a 1 Hz basis.				O, P						O	
Contact	12820	R	Sensor Report Event recipients shall support a 1 Hertz rate for receiving Events.				1						1	
Contact	12822	O	The Sensor Report Event provider shall provide sensor report events which reference sensor reports containing ownship position data.				O							

Sequence No.

Subsystem Allocation

Subsystem Allocations

Facilitators work with subsystems to generate IDL per requirement

IDL

```
/** @file soundingDepths_cs.idl
 * @b Classification: UNCLASSIFIED
 *
 * @version 0.0 1 August 2001 Initial
 */
#ifndef _soundingDepths_cs_idl_
#define _soundingDepths_cs_idl_
#include "navigation_t.idl"
/**
 * Description: The following is the definition for the sounding depths
 *              client/server interface.
 */
interface soundingDepths_cs {
   /**
    * Description:
    * @return navigation_t::soundingsDepths_t
    */
   navigation_t::soundingsDepths_t getSoundingDepths( );
}; // end soundingDepths_cs
#endif // _soundingDepths_cs_idl_
```

IDL Embedded In Subsystem Application

IIDB (CORBA) - Used to verify subsystem I/F

Data Group	Interface Name	Namespace Name	Method	GRL Sequence Numbers	Comments	PP:ACINT	PP:ARCH	PP:ASDS	PP:CC	PP:CKTD	PP:DSVL	PP:ECS:NDP	PP:ESM	PP:IA	PP:Imaging
Contact	npes_SensorReportEv ents_ev::imagingSens orReportEvent_ev	NPES-.CONTACTS-.Imaging_Sensor_Report_ev-active	npes_SensorReportEvents_ev::imagingSensorReportEvent_ev::newImagingSensorReportEvent	2660, 12800, 12820, 13240, 13260, 15170, 15650, 16570	NBCR 021				O, P, 1						0, 1
Contact	npes_SensorReportEv ents_ev::imagingSens orReportEvent_ev	NPES-.CONTACTS-.Imaging_Sensor_Report_ev-active	npes_SensorReportEvents_ev::imagingSensorReportEvent_ev::updatedImagingSensorReportEvent	2660, 12800, 12820, 13160, 13180, 15170, 15650, 16570	NBCR 021				O, P, 1						0, 1
Contact	npes_SensorReportEv ents_ev::imagingSens orReportEvent_ev	NPES-.CONTACTS-.Imaging_Sensor_Report_ev-active	npes_SensorReportEvents_ev::imagingSensorReportEvent_ev::updatedImagingStaticReportEvent	2660, 12800, 12820, 13120, 13140, 15170, 15650, 16570	NBCR 021				O, P, 1						0, 1
Contact	npes_SensorReportEv ents_ev::radarSensor ReportEvent_ev	NPES-.CONTACTS-.Radar_Sensor_Report_ev-active	npes_SensorReportEvents_ev::radarSensorReportEvent_ev::deleteRadarSensorReportEvent	2660, 12800, 12820, 13560, 13580, 15170, 15650, 16570	NBCR 021				O, P, 1						0, 1

Subsystem Allocations

Linked to a particular interface data rate

Auto generated from IDL

GDD

IDL File Name	Method(s) Producing Data
npes_SensorReportEvents_ev.idl	npes_SensorReportEvents_ev::esmSensorReportEvent_ev::newEsmSensorReportEvent, npes_SensorReportEvents_ev::imagingSensorReportEvent_ev::newImagingSensorReportEvent, npes_SensorReportEvents_ev::radarSensorReportEvent_ev::newRadarSensorReportEvent, npes_SensorReportEvents_ev::sonarSensorReportEvent_ev::newSonarSensorReportEvent, npes_SensorReportEvents_ev::srwsSensorReportEvent_ev::newSrwsSensorReportEvent
npes_SensorReportEvents_ev.idl	npes_SensorReportEvents_ev::esmSensorReportEvent_ev::newEsmSensorReportEvent, npes_SensorReportEvents_ev::imagingSensorReportEvent_ev::newImagingSensorReportEvent, npes_SensorReportEvents_ev::radarSensorReportEvent_ev::newRadarSensorReportEvent, npes_SensorReportEvents_ev::sonarSensorReportEvent_ev::newSonarSensorReportEvent, npes_SensorReportEvents_ev::srwsSensorReportEvent_ev::newSrwsSensorReportEvent

Method: programmed procedure within an interface

Interface Working Group Participants

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Infrastructure:	***Navigation:***	***Contact Data:***	***On-Board Training:***	***Hull/Mechanical Data***	***Communications:***	***Environmental Data:***
Lockheed Martin *Progeny* *Electric Boat* *GD-AIS* *NUWC*	*Lockheed Martin* *Northrop Grumman*	*Raytheon* *GD-AIS* *Lockheed Martin* *Kollmorgan* *NUWC*	*Electric Boat* *Lockheed Martin*	*Electric Boat* *NUWC*	*Electric Boat* *Lockheed Martin* *NUWC* *SPAWAR*	*Lockheed Martin* *GD-AIS* *Electric Boat*

- Integrated Product Team structure to develop and maintain interface specifications and products (GRL, IDL, GDD, Network Design, Information Assurance)
- Adopts widely used standards, data formats, and protocols
- Defines key attributes of the network and services
- Consensus-based interface definition and design

"The key is in designing an architecture that is going to take advantage of commercial standards, the ability to pull pieces out and reuse them in other systems and platforms, and that allows third parties access"
Delores Etter, Assistant Secretary of the Navy for RDA

Interface Layers

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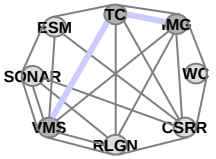
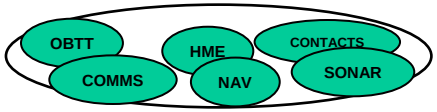
Yesterday → Today





Generic Data Transfer Model

- **Semantic**
  - •Data Interpretation
- **Behavioral**
  - •Message Sequencing
  - •Fault/Fail Schema
- **Syntax**
  - •Data Field Definition
- **Interface Protocol**
  - •I/O HW and SW

NTDS Data Transfer Model

Subsystems Domain

- Application Code (IDS / SRS)
- I/O Application Code (IDS)
- NTDS Protocol / Driver (NTDS Spec)
- NTDS | NTDS

CORBA Data Transfer Model

Subsystem Domain

- Application Code (GRL / SRS / GDD)

Shared (System and Subsystem) Domain

- CORBA Application Code (GRL, SIFT, GDD)
- Common IDL

System Domain

- Network Protocol (Network Spec)
- NIC | NIC
- Network
- Name Services | Time Services

Interface Management designed in to streamline integration by reducing/eliminating at each of the layers of the Interface

SE&I Toolset

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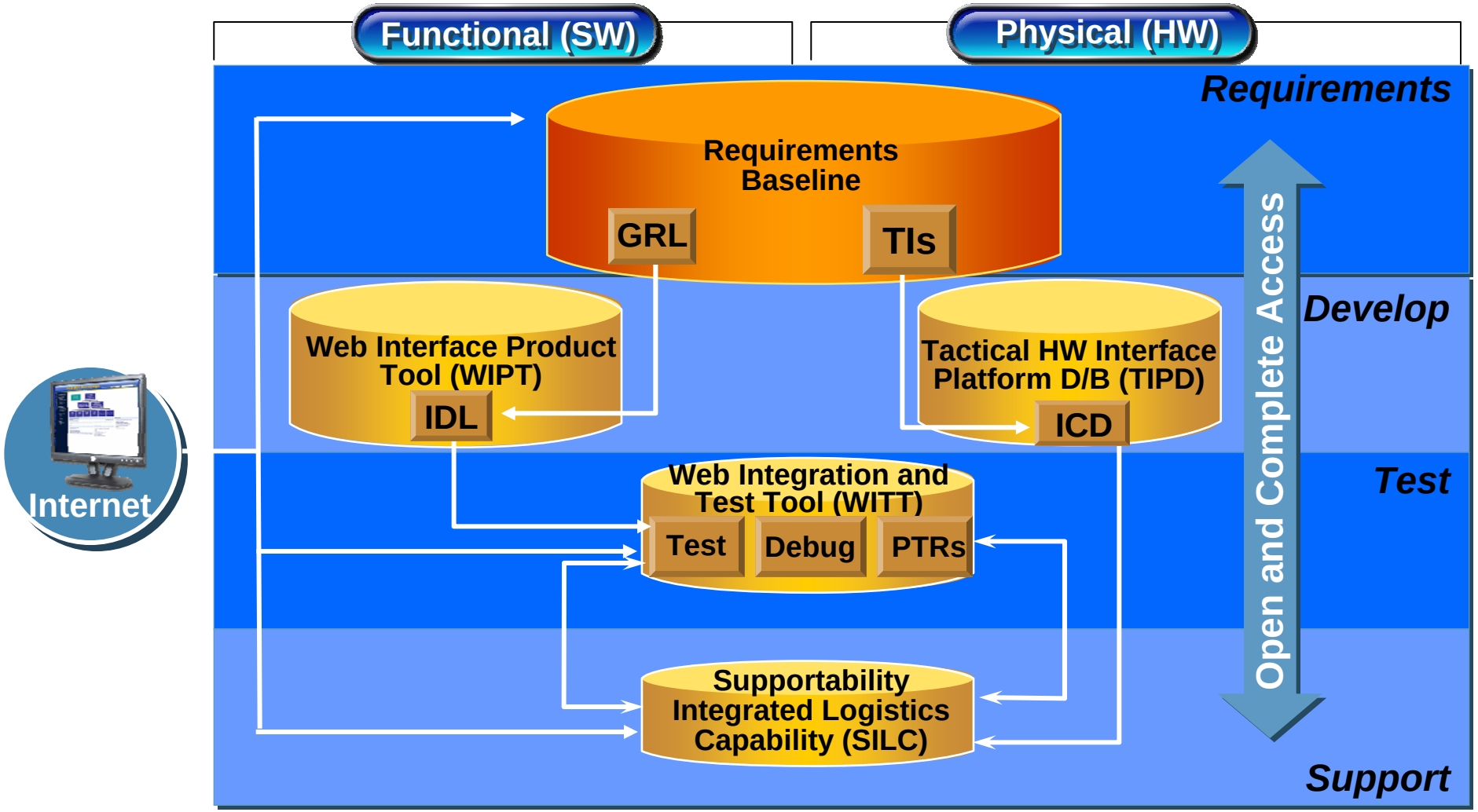

Fully integrated and web-enabled toolset for SE&I

What's next?

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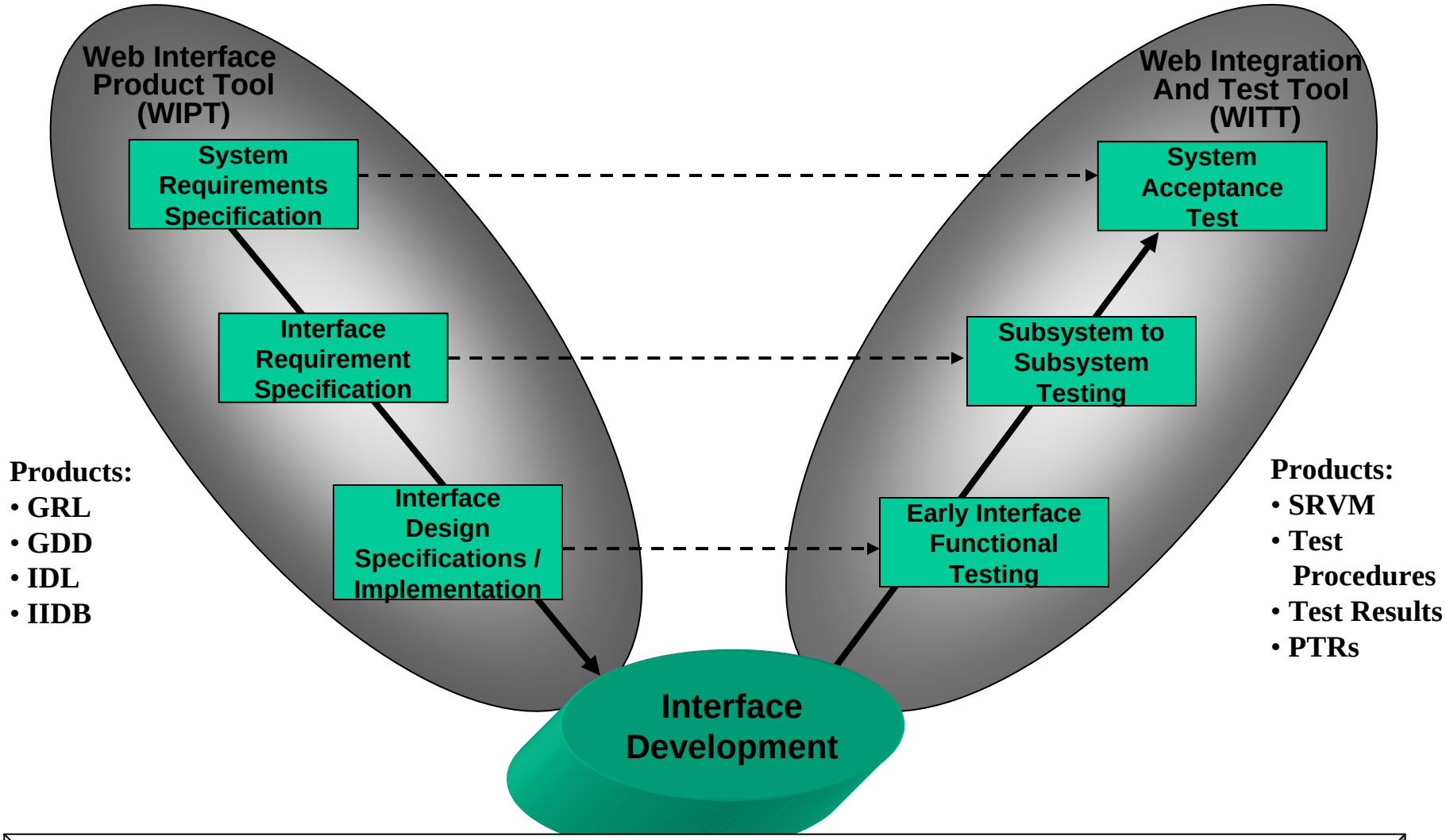
- It doesn't end with Interface Management!
  - Systems engineering processes and products must be balanced with integration products and processes
  - There is an inherent relationship between standards, interface engineering and system integration
    - System definition
    - Interface design and development
    - System test and integration
  - The confluence of an open systems architecture, standards and system integration leads to:
    - Easier technology insertion
    - Fielding capability faster
    - Streamlined system integration

SE&I is a balanced approach between interface management, standards and system integration

SE&I Process and Products



Fully integrated and web-enabled toolset for SE&I

Test and Integration
(The "I" in SE&I)

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Goals:

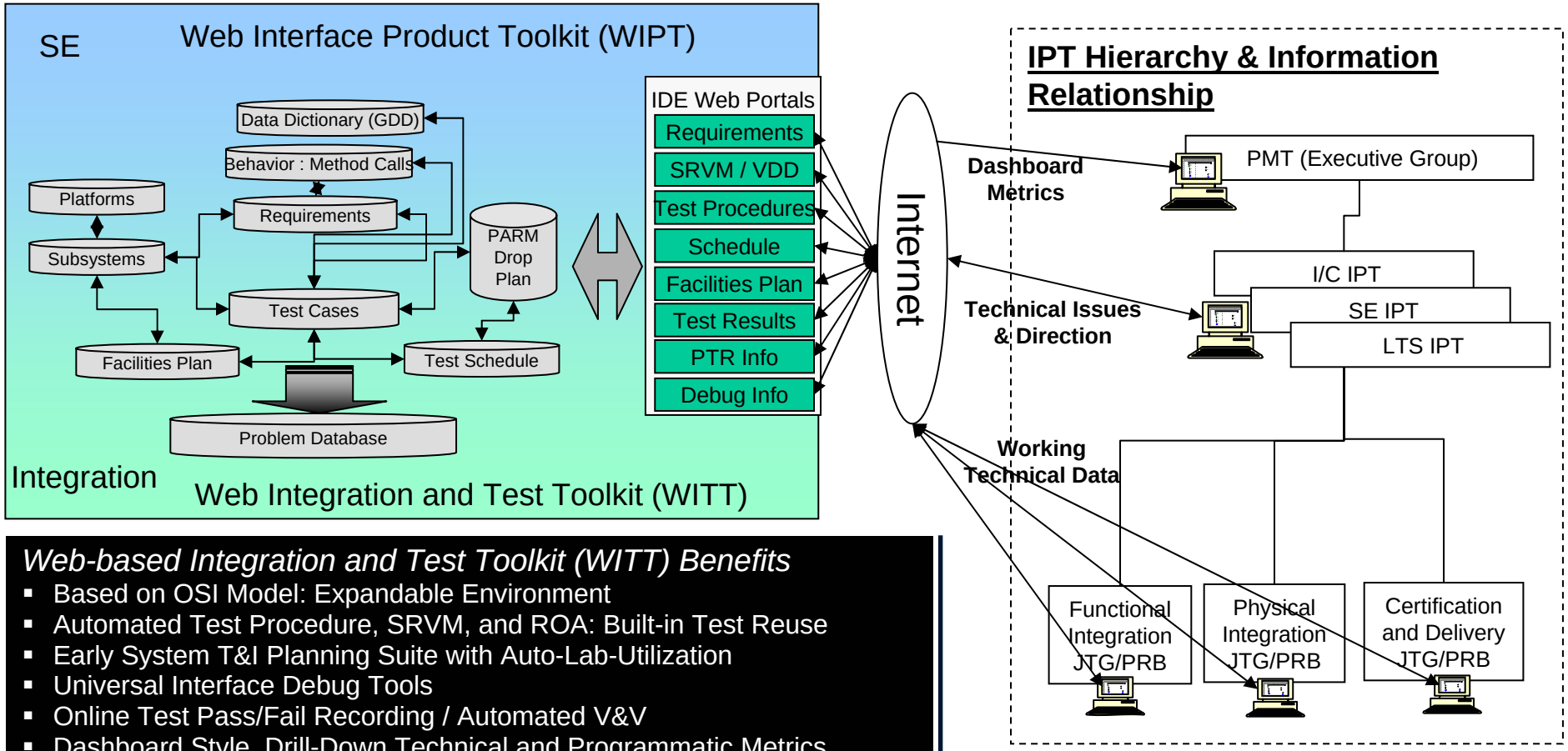
- Achieve a single integrated, cohesive working Combat System
- Risk Mitigation
- Cost containment
- Schedule Control
- Optimize Government and Industry Lab resources
- Early integration and test of interfaces
- Pull integration and Lifetime Support issues from the fleet and solve in labs

Approach:

- Virtual Integration Facilities to optimize capital investments
- Structured interface testing
- Allow collaborative debug of problems from development lab
- Distribution of software builds/patches
- Remote access to development environments
- Responsiveness to Fleet needs
- Support Certification

Networked Labs and Collaboration Provide Mechanisms for Early Integration Testing to Minimize Risk

Automated SE&I Toolkit



Web-based Integration and Test Toolkit (WITT) Benefits

- Based on OSI Model: Expandable Environment
- Automated Test Procedure, SRVM, and ROA: Built-in Test Reuse
- Early System T&I Planning Suite with Auto-Lab-Utilization
- Universal Interface Debug Tools
- Online Test Pass/Fail Recording / Automated V&V
- Dashboard Style, Drill-Down Technical and Programmatic Metrics

Web-Enabled SE&I Toolkit Connects all Stakeholders

System Engineering & Integration Approach: Test What has Changed; When it is ready

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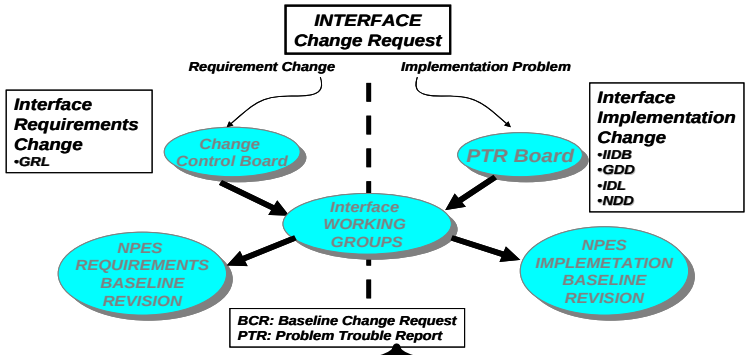
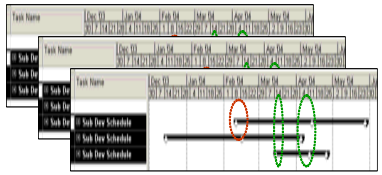


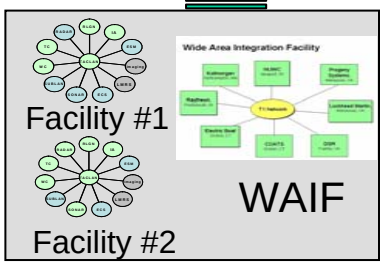


Subsystem Schedules

- Prioritization
- Debug
- Problem Isolation
- Resolution
- Verification

Interface Requirements → Group Products → Test Case Matrix → Test Schedule & Conduct → PTR Adjudication

Test Case Matrix → Facilities Plan



		Subsystem Assessment											IT&E	
NBCR #	Title	TC	WC	Taclan	Sonar	NAV	RADAR	SUBLAN	RADIO	ESM	Imaging	Implemen-tation	Schedule
xxx-750	Update to IPv06	C	C	P	C	C	C	P	P	C	C	H	L
1132-	Net-Centric Warfare (NCW) Distance Support	P			P			C	C			M	L
1133-	Digital Navigation Computer to Computer Information Transfer	P	C	C	C	C	C		P		C	M	L
xxxx-	Consolidation of Displays	PC	PC	PC	PC	PC	PC			PC	PC	H	M
968-	GRL Mapping in IIDB is incorrect	P			C							M	L
047-750	Add Transverse coordinate system data elements to sensor and contact reports	C	C		P		P			P	P	M	M
Other	Network Loading	M	H	M	M	M			M	M	H	H	L
Other	Off-Hull Bandwidth	M		M					M		H	H	M
Other	Taclan Switch Changes	L	H	L	L	L	L	L	L	L	L	H	L

System Integration approach has evolved through several iterations and provides complete management of Requirements, Tests, Facilities, Drops, and PTRs

Lessons Applied

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- Be prepared for a major cultural change and manage it!
- Adopt standards widely developed/recognized by industry
- Focus on interface management not subsystem development
- Strive for consensus-based interface definition on all key interfaces early
- New business models and processes will be required
- Link functionality updates (APBs) to bundled interface baseline updates
- Be prepared to migrate with technology (standards lag the technology curve)
- All interfaces are not created equal
- Consider and develop a strategy for information assurance, fault management and fail-over early. Most standards ignore these areas!
- Plan for change!

Interface management is the key!