Multiple Independent Levels of Safety & Security (MILS): High Assurance Architecture

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OBJECTIVE INTERFACE

What is High Assurance?

- To the FAA:
  - One failure per 10^9 (1 Billion) hours of operation
    - How long *is* a Billion hours? Do the math!
      - $1{,}000{,}000{,}000\,\text{hours} \times \frac{1\,\text{day}}{24\,\text{hours}} \times \frac{1\,\text{year}}{365.25\,\text{days}}$
      - 114,077 *YEARS!*

- For National Security Systems processing our most valuable data under most severe threat:
  - Failure is *Unthinkable*

- ***How do we implement systems that we can trust to be this robust?***

Industry Standards

- RTCA DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*
- ARINC-653, *Avionics Application Software Standard Interface*
- ISO-15408, *Common Criteria for Information Technology Security Evaluation*
- DCID 6/3, *Protecting Sensitive Compartmented Information Within Information Systems*

Assurance Certification Goals

Common Criteria	***MSLS / MLS Separation Accreditation***
Basic Robustness (EAL3)	System High Closed Environment
Medium Robustness (EAL4+)	System High Open Environment
High Robustness (EAL6+)	Multi Level Separation
DCID 6/3 Protection Level 5	***Multi Nation Separation Accreditation***
DO-178B Level A	***Failure is Catastrophic***

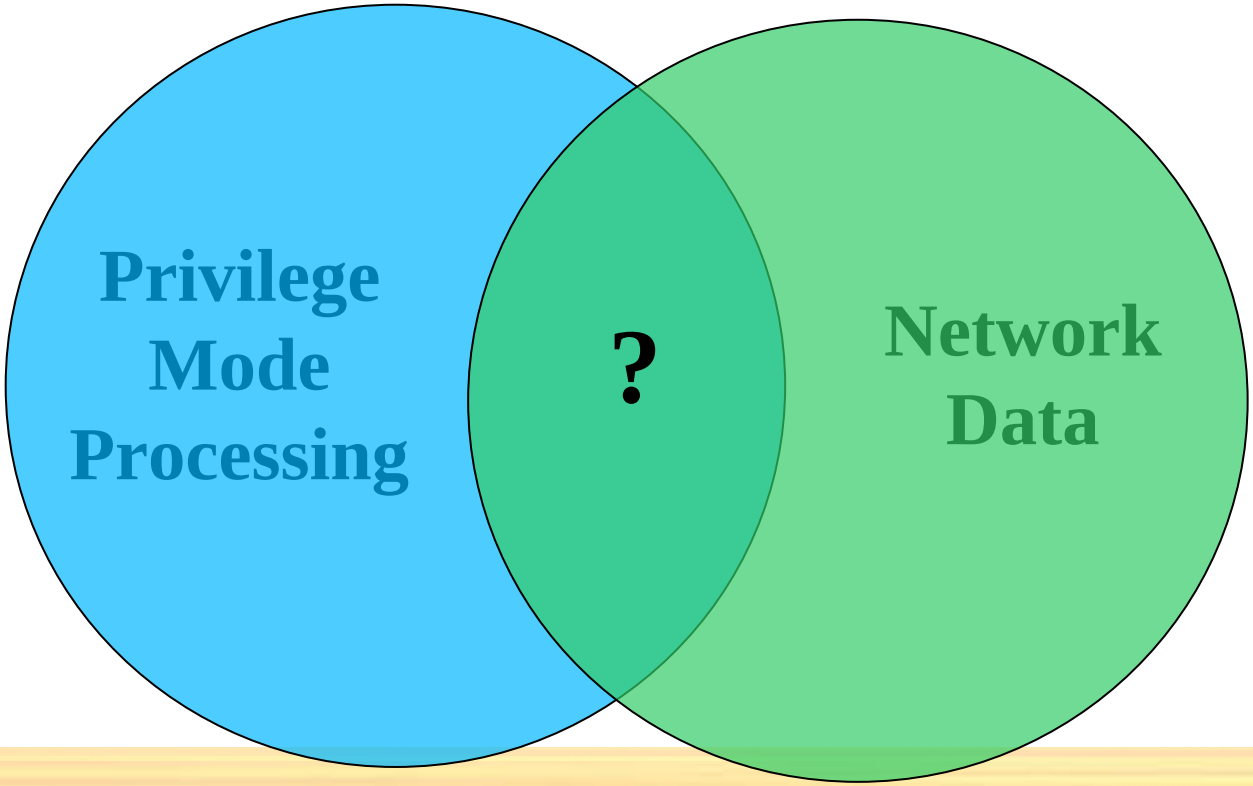
Fail-first, Patch-later

- Most commercial computer security architectures
  - The result of systems software where security was an afterthought
    - Operating systems
    - Communications architectures
  - **Reactive** response to problems
    - Viruses, Worms, and Trojan Horses
    - Hackers and Attackers
    - Problems are only addressed ***after*** the damage has been done

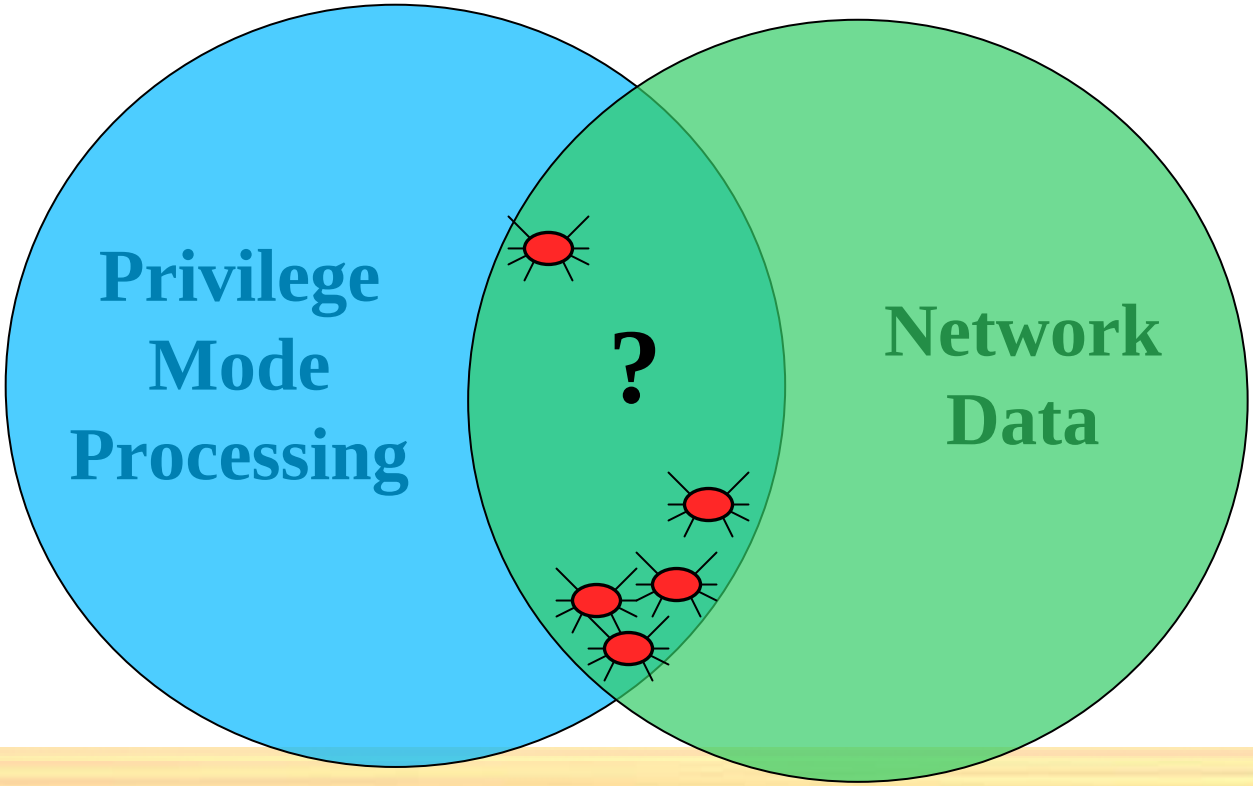
- Inappropriate approach for mission critical systems
  - Does not safeguard information or the warfighter
  - **Proactive** measures are required to ***prevent*** damage

Fail-first, Patch-later (cont.)

- **Reactive** approach failures:
  - How many PC anti-virus programs can detect or quarantine malicious device drivers?
    - *None!*
  - What can an Active-X web download do to your PC?
    - *Anything!*

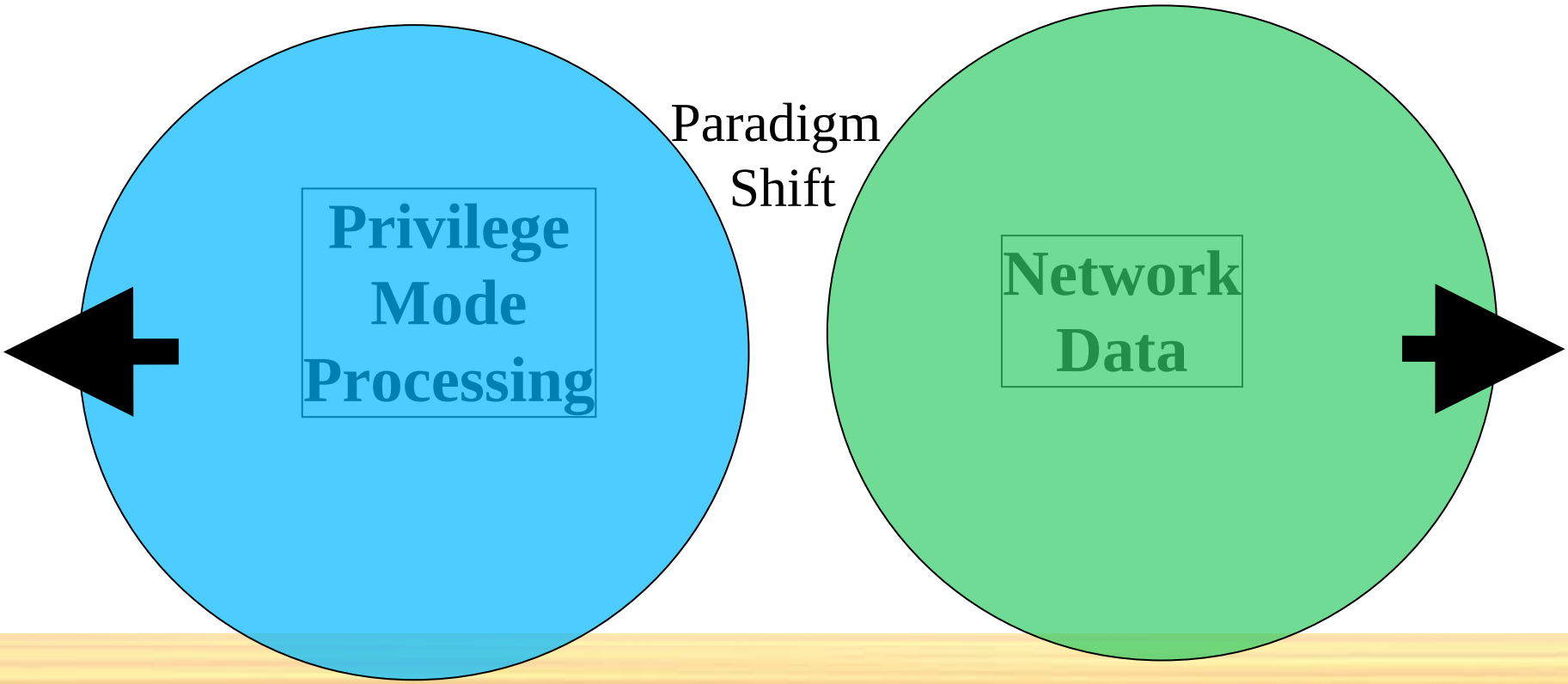


What happens when network data is processed in privilege mode?



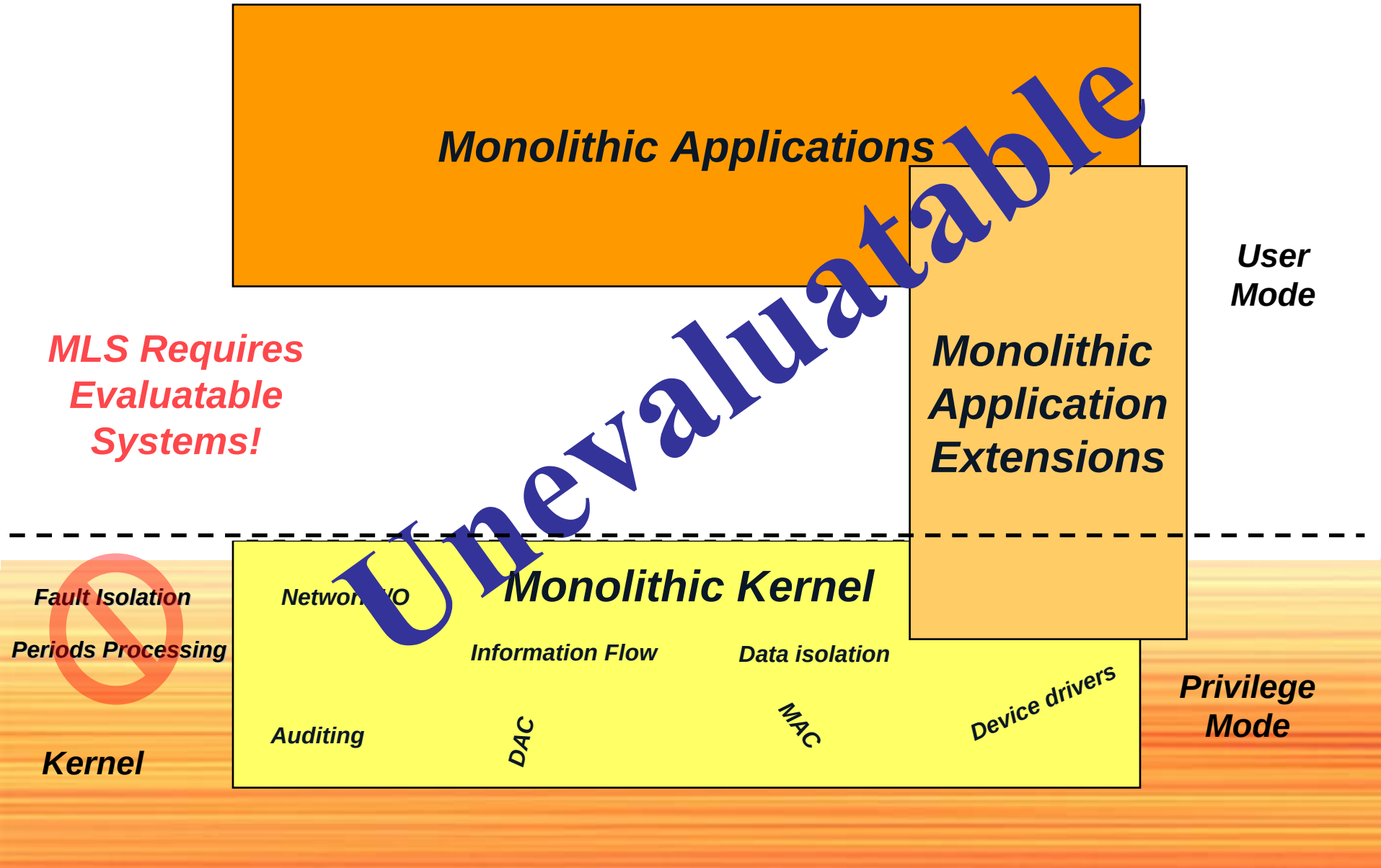
Wild Creatures of the Net: Worms, Virus, . . .

MILS Security Policy



Under MILS Network Data and Privilege Mode Processing are Separated

Where We've Been: Starting Point for Architectural Evolution



Really very simple:

- Dramatically reduce the amount of *safety/security critical code*

So that we can

- Dramatically increase the scrutiny of *safety/security critical code*

The MILS Architecture

Three distinct layers (John Rushby, PhD)

- Separation Kernel
  - Separate process spaces (partitions)
  - Secure transfer of control between partitions
  - Really small: 4K lines of code
- Middleware
  - Application component creation
  - Provides secure end-to-end inter-object message flow
    - Device Drivers, File Systems, Network Stacks, CORBA, DDS
- Applications
  - Implement application-specific security functions
    - Firewalls, Cryptomod, Guards, Mapplet Engine, CDS, Multi-Nation Web Server, etc.

The MILS Architecture (cont'd)

Separation Kernel

- **Microprocessor Based**
  - Time and Space Multi- Threaded Partitioning
  - Data Isolation
  - Inter-partition Communication
  - Periods Processing
  - Minimum Interrupt Servicing
  - Semaphores
    - Synchronization Primitive's
  - Timers

And nothing else!

MILS Middleware

- **Traditional RTOS Services**
  - Device Drivers
  - File Systems
  - Token and Trusted Path
- **Traditional Middleware**
  - CORBA (Distributed Objects)
  - Data Distribution (Pub-Sub)
  - Web Services
- **Partitioning Communication System (PCS)**
  - Global Enclave Partition Comm
    - TCP, UDP, Rapid-IO, Firewire, …
  - Partition Based Attestation

Why Does Neatness Count?

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T

Safety and Security enforcing functions must be:

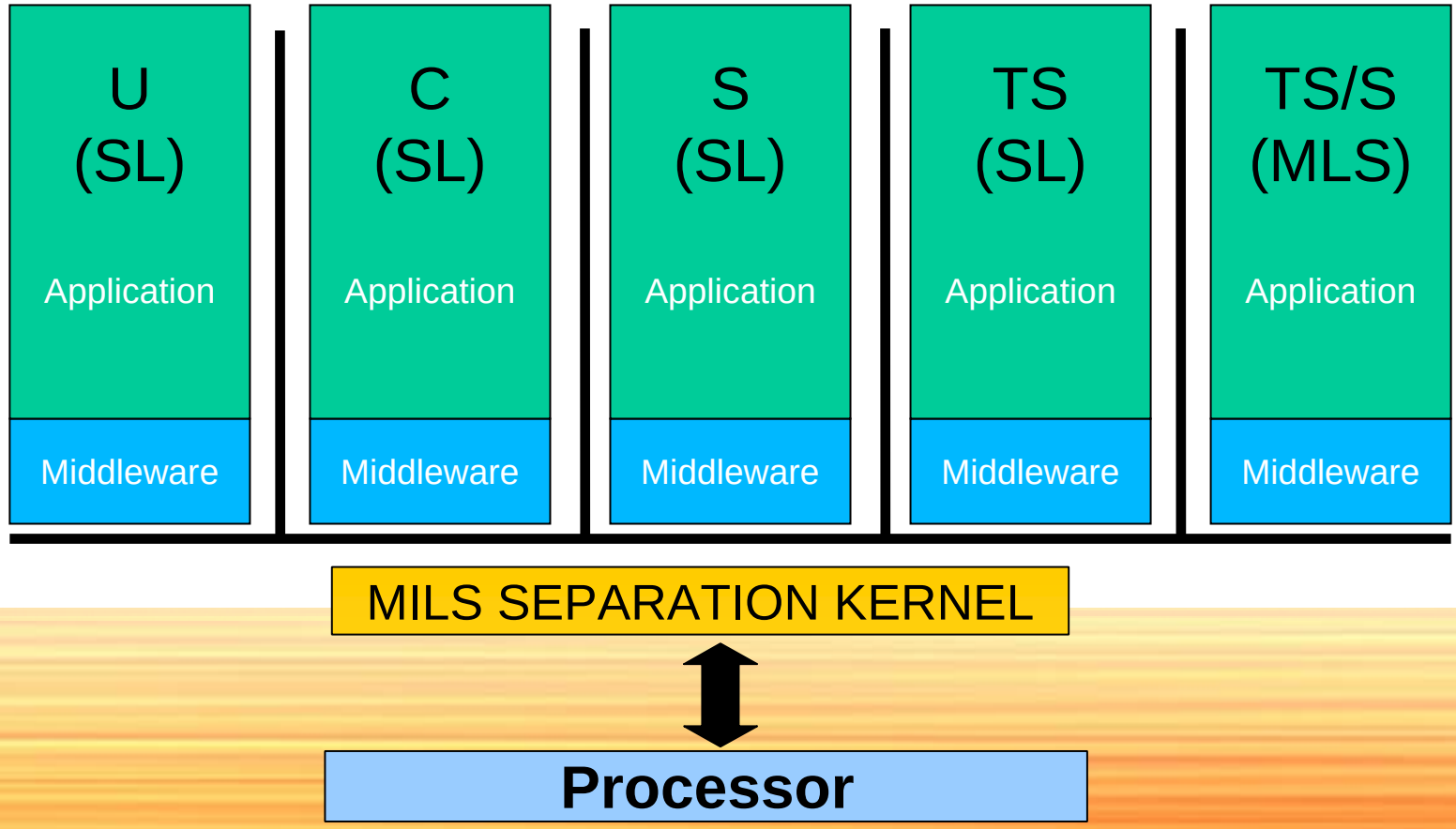
- ***N***on-bypassable
  - Enforcing functions cannot be circumvented
- ***E***valuatable
  - Enforcing functions are small enough and simple enough for mathematical verification
- ***A***lways Invoked
  - Enforcing functions are invoked each and every time
- ***T***amperproof
  - Subversive code cannot alter the enforcing data or functions

MILS Architecture Evolution

Multiple Independent Levels Of Safety And Security (MILS): High Assurance Architecture

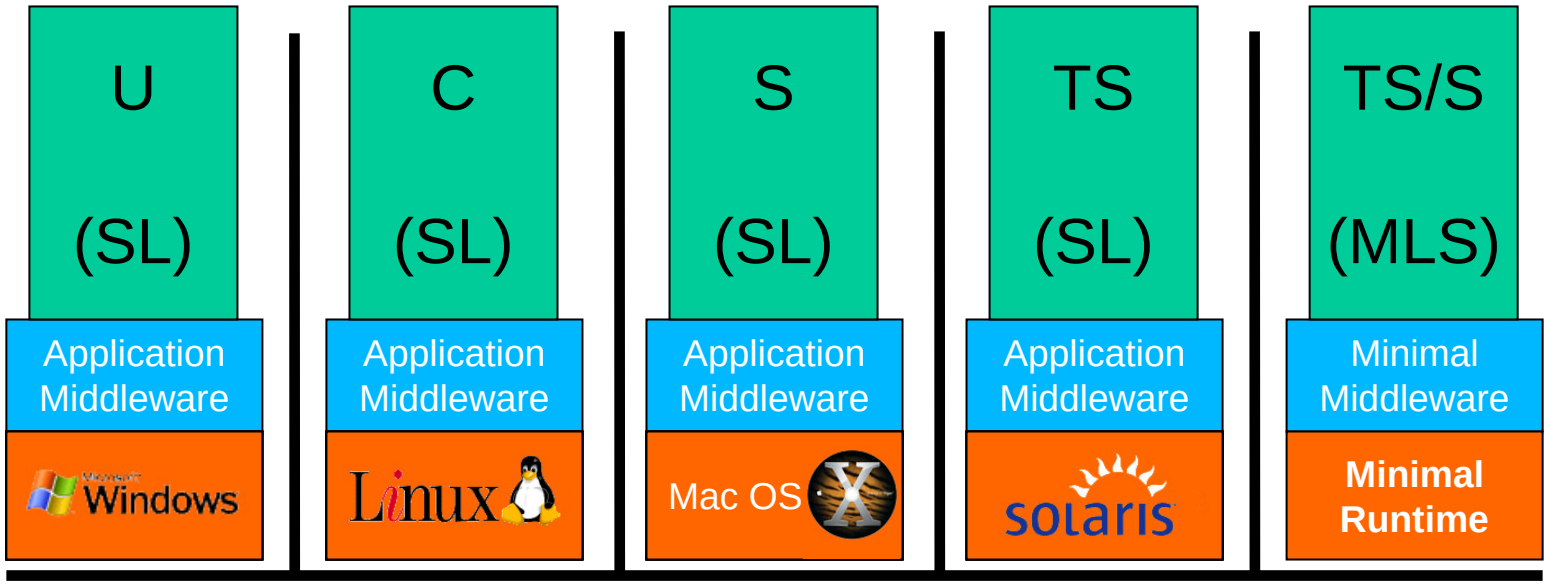
The MILS Architecture

Multiple Independent Levels Of Safety And Security (MILS): High Assurance Architecture



Guest OS Architecture

Multiple Independent Levels Of Safety And Security (MILS): High Assurance Architecture



A MILS Workstation? (later…)

Processor

Distributed Security Requirements

- Extend single node enforcement to multiple nodes
- Do not add new threats to data Confidentiality or Integrity
- Enable distributed Reference Monitors to be **NEAT**
- Optimal inter-node communication
  - Minimizing added latency (first byte)
  - Minimizing bandwidth reduction (per byte)
- Fault tolerance
  - Infrastructure must have no single point of failure
  - Infrastructure must support fault tolerant applications

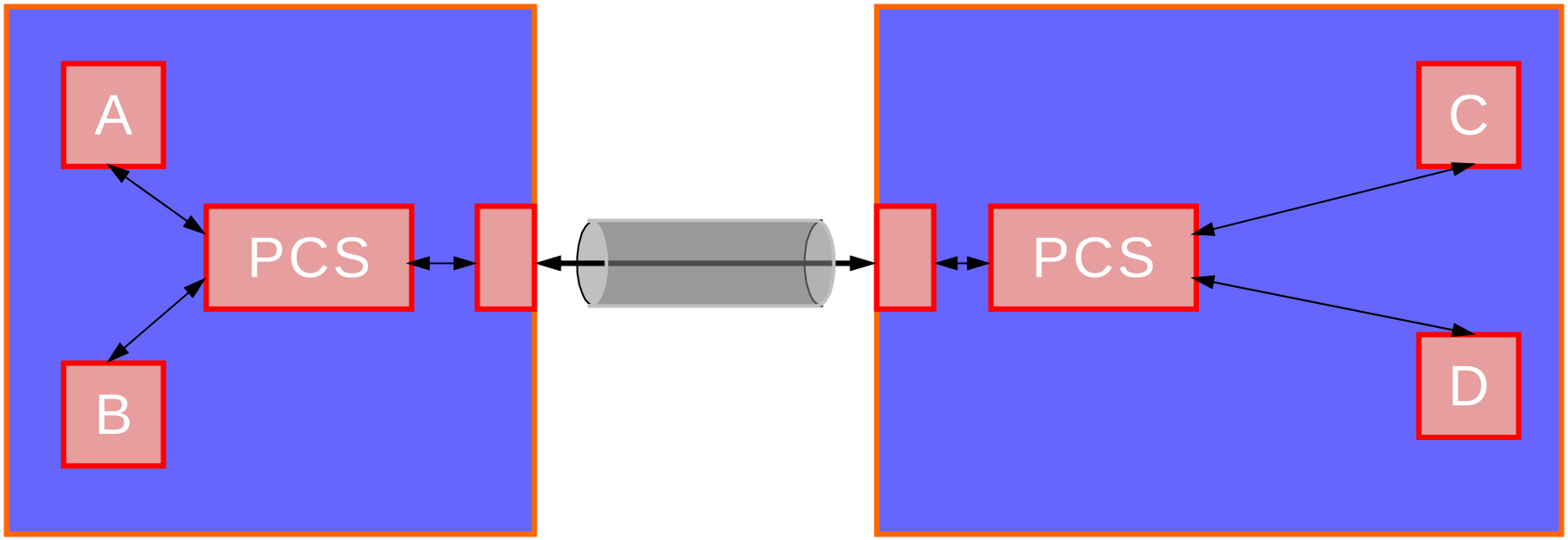
The Partitioning Communications System

- The Partitioning Communications System (PCS) is communications middleware for MILS
- Always interposed in inter-node communications
- Interposed in some intra-node communications also
- Parallels Separation Kernel's policies

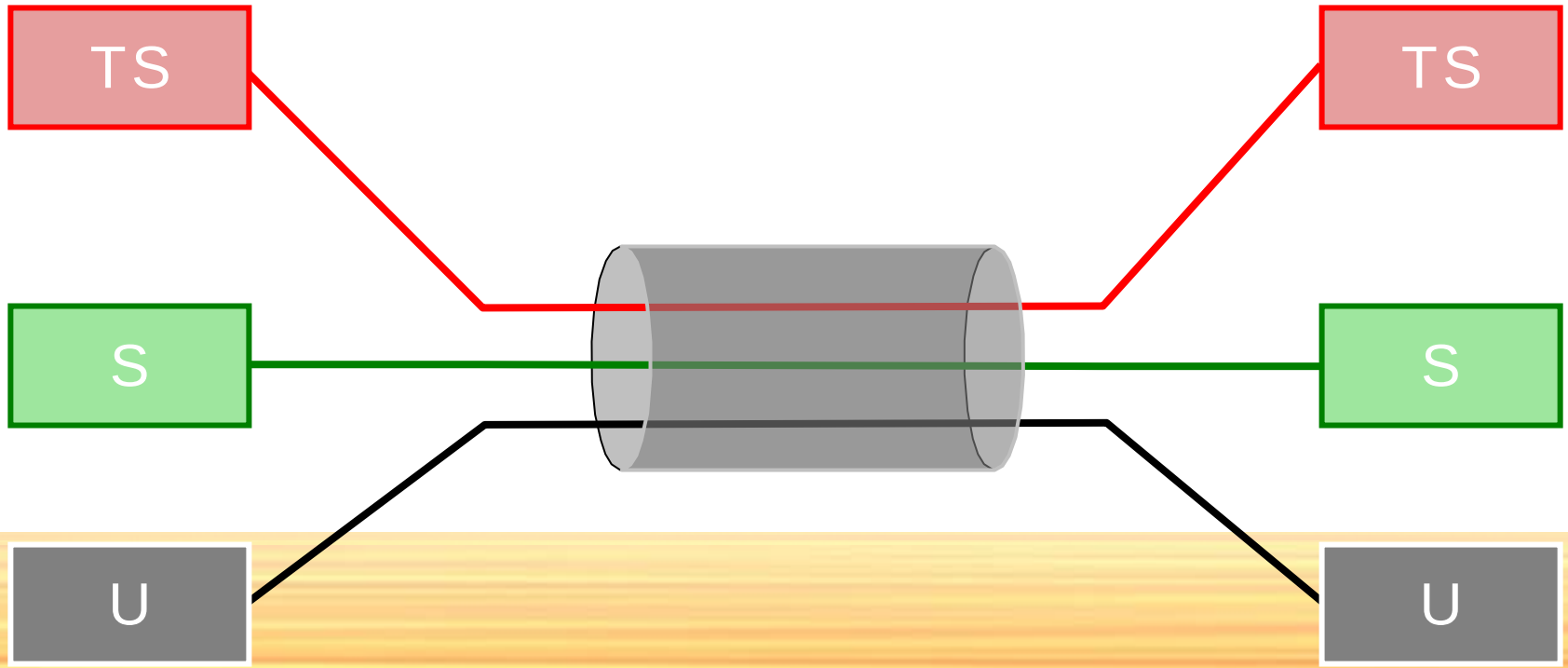
PCS Specific Requirements

- Strong Identity
  - Nodes within enclave
- Separation of Levels/Communities of Interest
  - Need cryptographic separation
- Secure Configuration of all Nodes in Enclave
  - Federated information
  - Distributed (compared) vs. Centralized (signed)
- Secure Loading: signed partition images
- Secure Clock Synchronization
- Suppression of Covert Channels
  - Bandwidth provisioning & partitioning
  - Network resources: bandwidth, hardware resources, buffers

Inter-node Communication

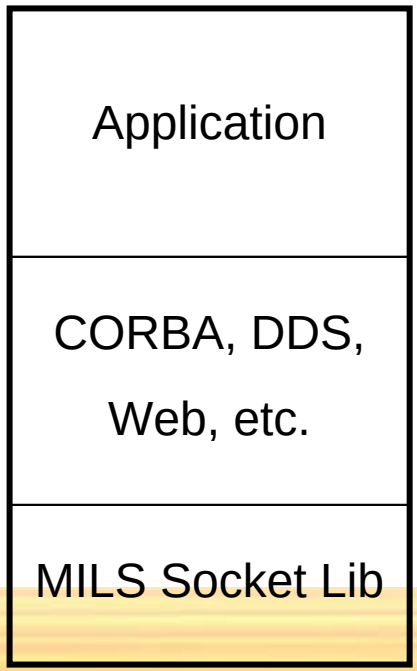


Partitioning the Channel

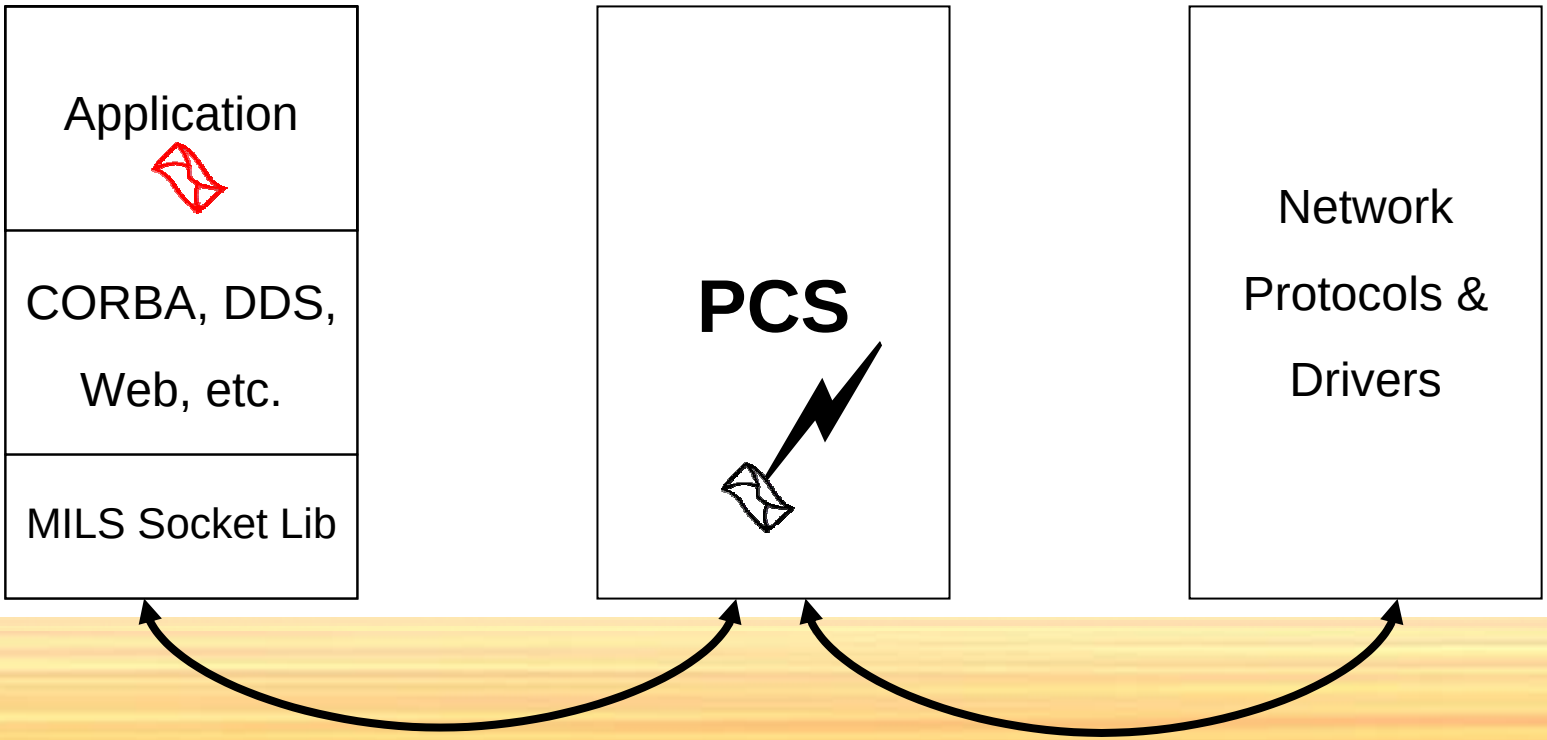


Network Middleware Libraries

- Network middleware provides libraries for application use
  - e.g.,
    - Real-time CORBA
    - Data Distribution Service
    - DBMS libraries
    - Web-based libraries (.NET, Web Objects, etc.)
  - Run in application partitions
  - Provide application with higher level interface to network libraries (eg. Socket libraries)
- Some applications use socket libraries directly



System Architecture with PCS



PCS Cross-Node Information Flow

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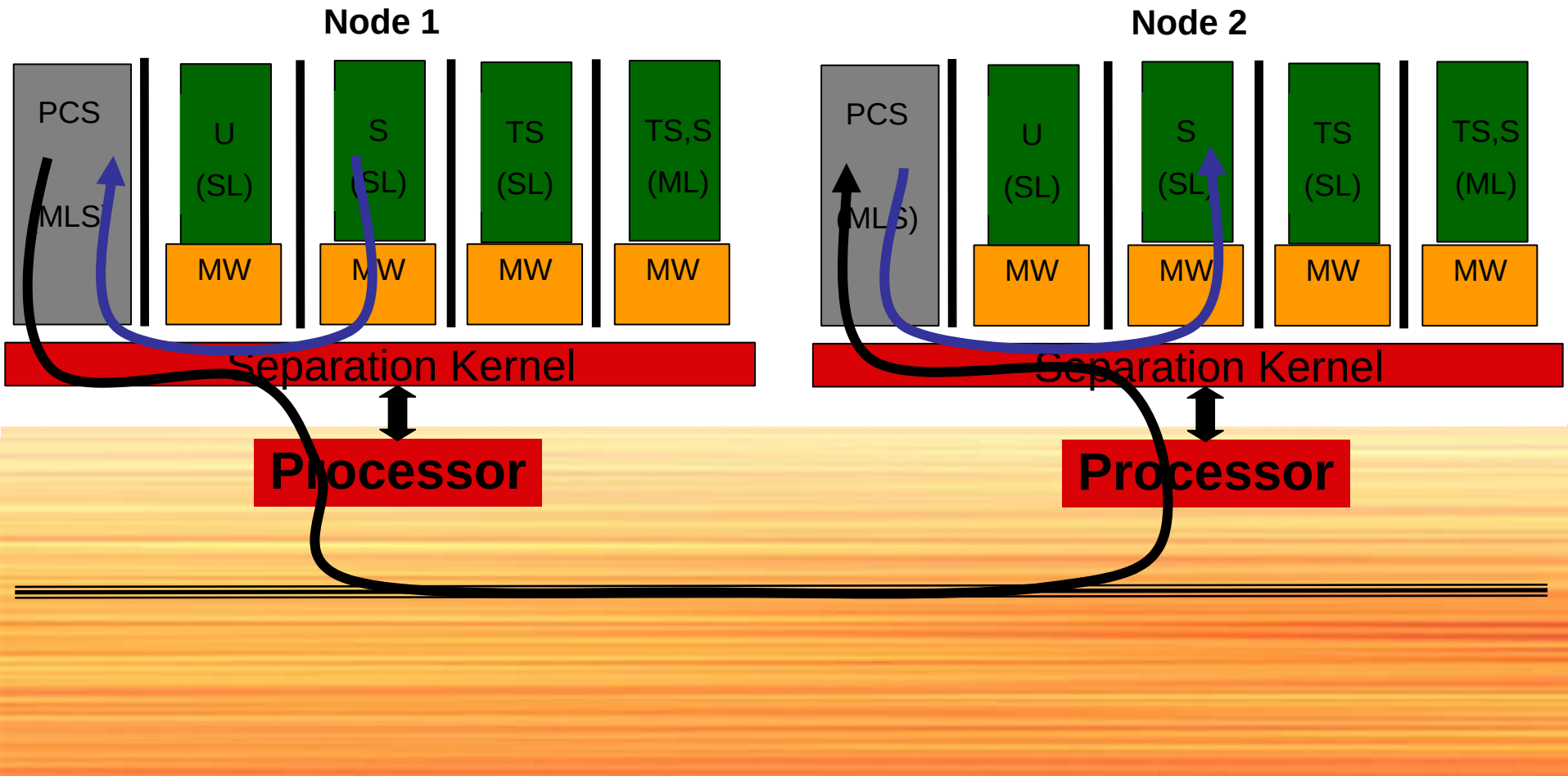


Real-time MILS CORBA

- Real-time CORBA can take advantage of PCS capabilities
  - Real-time CORBA + PCS = Real-time MILS CORBA
  - Additional application-level security policies are enforceable because of MILS SK and PCS foundation
- Real-time MILS CORBA represents a single enabling application infrastructure

RT CORBA & MILS Synergy

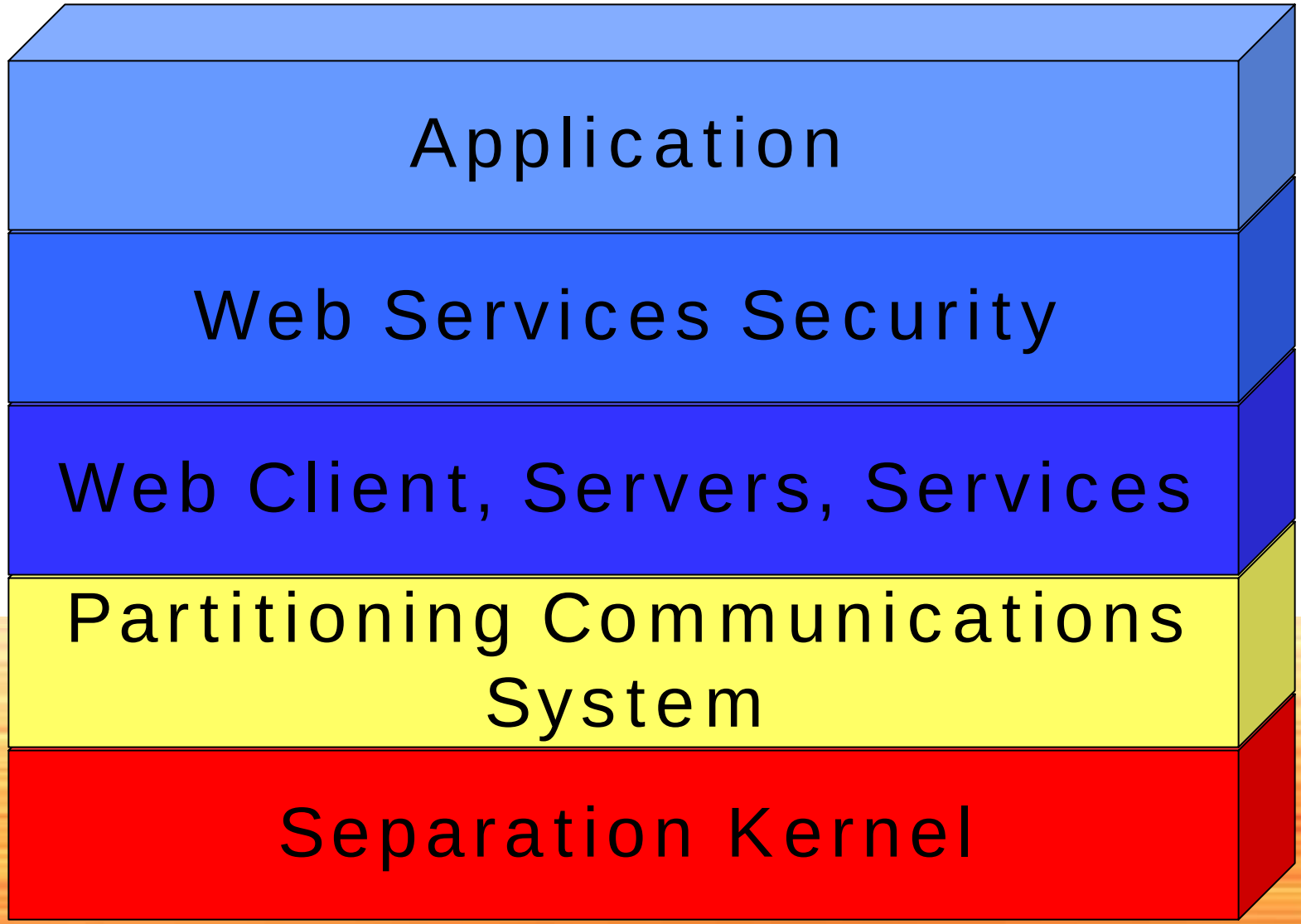
- Synthesis yields an unexpected benefit
  - Flexibility of Real-time CORBA allows realization of MILS protection
  - **MILS is all about location awareness**
    - Well designed MILS system separates functions into separate partitions
    - Takes advantage of the MILS partitioning protection
  - **Real-time CORBA is all about location transparency**
    - The application code of a properly designed distributed system built with Real-time CORBA will not be aware of the location of the different parts of the system.
    - CORBA flexibility allows performance optimizations by rearranging what partitions each system object executes in.
    - System layout can be corrected late in the development cycle
  - Combination of MILS and Real-time CORBA allows system designer
    - ***Rearrange system functions to take advantage of protection without introducing new threats to data confidentiality and integrity***

MILS DDS

- OMG Data Distribution Specification
  - Data-centric publish-subscribe
- PCS protects DDS implementations from
  - Attack by other partitions
  - Network attacks
  - Covert channels
- DDS can take advantage of PCS capabilities
  - PCS + DDS = MILS DDS
  - Application-level security policies are enforceable because of MILS SK and PCS foundation

Web Services Overview

- The Web is all about the user interface
- Web Services are all about providing dynamic services driven from and to feed the user interface
- Programmable application logic accessible using standard Internet protocols


Application
Web Services Security
Web Client, Servers, Services
Partitioning Communications System
Separation Kernel

High Assurance MILS Workstation

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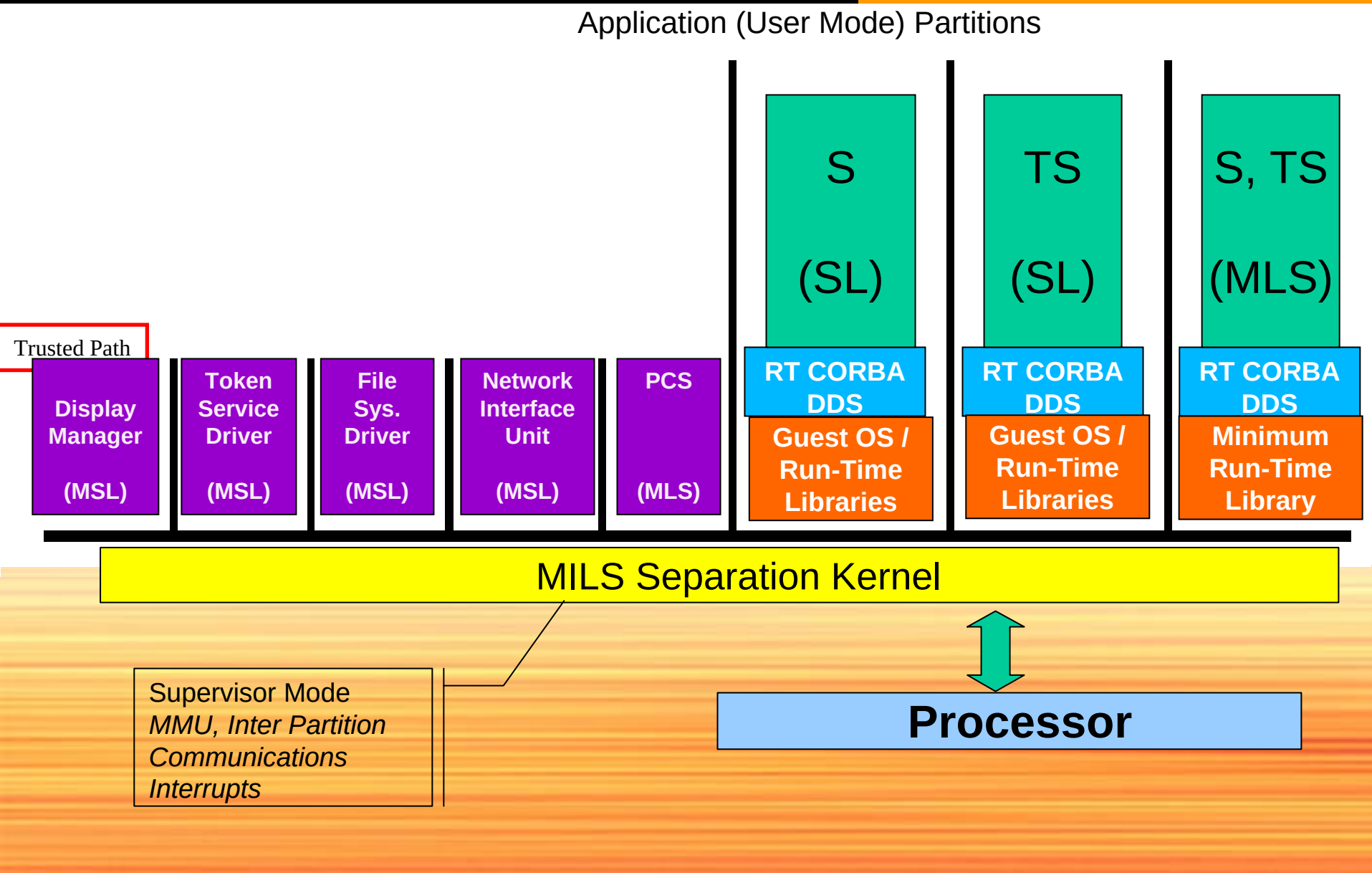

MILS Workstation Network Access

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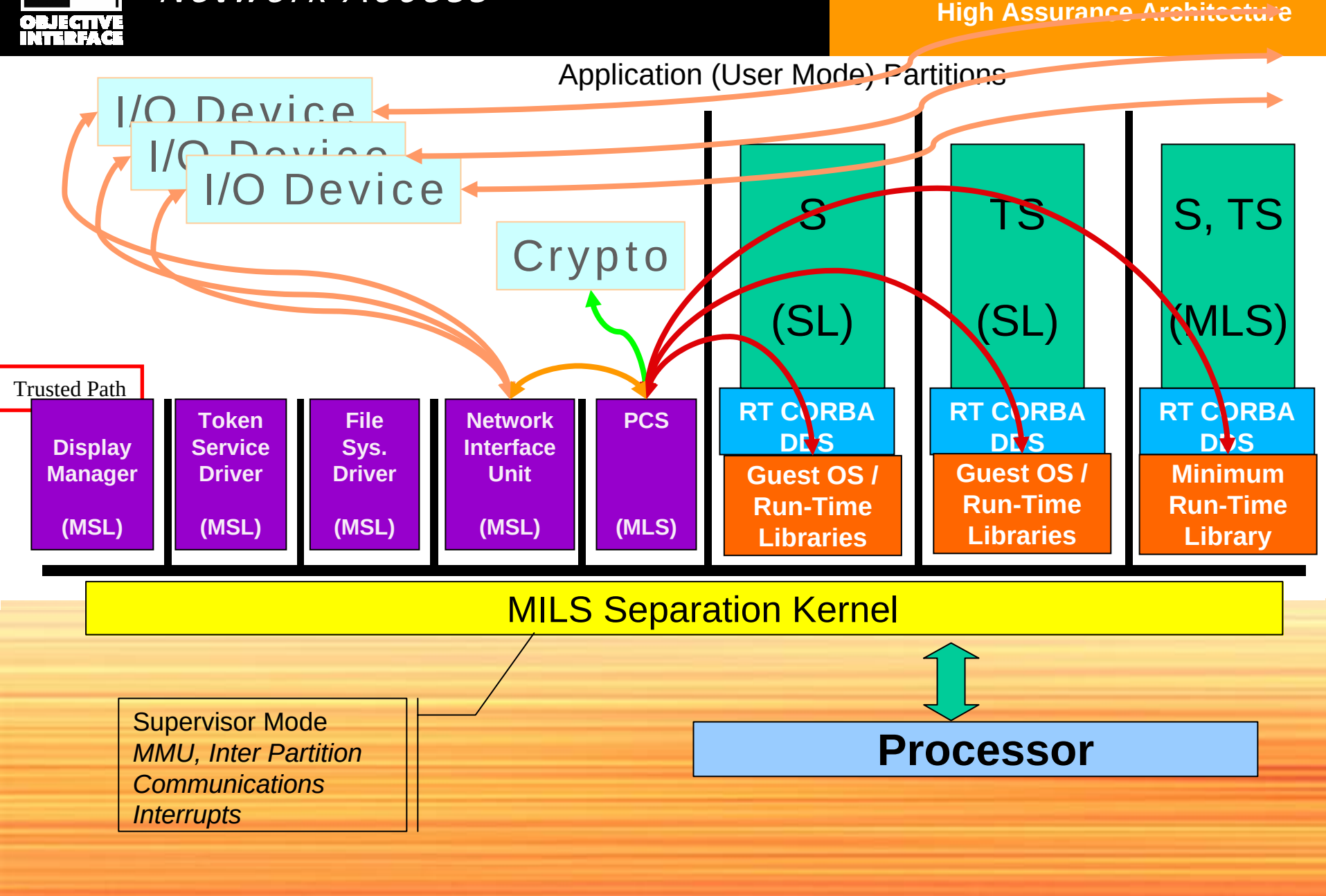

The Whole Point of MILS

Really very simple:

- Dramatically reduce the amount of *safety/security critical code*

So that we can

- Dramatically increase the scrutiny of *safety/security critical code*

To make

- Development, certification, and accreditation more practical, achievable, and affordable.