Introduction

- Firewall mentality
  - on the Internet the cornerstone of security is the notion of a firewall
  - a logically bounded system within a physically unbounded one
  - bounded-system thinking within unbounded domains can lead to security designs and architectures that are fundamentally flawed from a survivability perspective
  - firewalls are state of the art for security systems but not for survivable systems
  - firewalls are passive and implement filter functions
  - how “managed” is the firewall, i.e. is it configured effectively?
    » Danger: False sense of security!
Introduction

◆ Defining Requirements for Survivable Systems
  - Survivability requirements depend on main issues:
    » system scope
    » criticality
    » consequences of failure and interruption of service
  - In addition to software functionality, survivability must address requirements for
    » software usage,
    » development,
    » operation,
    » evolution.
Defining Requirements for Survivable Systems (cont)

- New paradigm characterized by:
  - distributed services
  - distributed logic
  - distributed code
  - distributed hardware
  - shared communications and routing infrastructure
  - diminished trust
  - lack of unified administrative control

- Paradigms formidable effort for software engineering research
  - traditional computer security measures are augmented by comprehensive system survivability strategies
Introduction

- Survivability Requirements
  - we now discuss each of the following topics briefly:
    » System/Survivability Requirements
    » Usage/Intrusion Requirements
    » Development Requirements
    » Operations Requirements
    » Evolution Requirements
Introduction

Figure 2: Requirements Definition for Survivable Systems
Introduction

- Survivability Requirements
  - refer to capability of system to
    » deliver essential services in the presence of intrusions
    » recover full services
  - system should be organized into essential and non-essential services
    » essential services
      ■ must be maintained even during successful intrusion
      ■ may have different levels,
        - “prioritize by severity and duration of intrusion”
      ■ must be augmented with survivability requirements
    » non-essential services
      ■ are recovered after intrusion has been handled
    » in this paper the view is “binary”, however that must not be the case
Introduction

System Requirements
- describe traditional user functions a system must provide
  - example: network management system must provide
    » monitoring of system, performance adjustments, etc.
  - may include non-functional aspects
    » timing, performance, reliability
Survivability Requirements (cont.)

- COTS components not developed with survivability objective
  - may provide both essential and non-essential services
  - may require functional requirements for isolation and control (using wrappers and filters)

- survivability imposes new requirements on system
  - resistance to, recognition of and recovery from malicious acts
  - adaptation and evolution
Introduction

Figure 3: Integrating Survivability Requirements with System Requirements

CMU/SEI-97-TR-013

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Introduction

System/Survivability Requirements (cont.)
- term *emergent behavior requirements* at network level
  » underlines that requirements are not associated with a particular node, but emerge from the collective behavior
  » issue is survivability of the overall network capability
    ■ e.g., message routing in the presents of topology degradation

- capability of adapting
  » behavior, function, resource allocation
  » resources may be shifted from non-essential to essential services
Introduction

- **System/Survivability Requirements (cont.)**
  - survivability requirements may vary greatly
    - small systems may only have non-essential services
      - (recovery in hours)
    - large systems (large networks) may have core set of essential services, automated intrusion detection
      - (recovery in minutes)
    - embedded control systems may require essential services in real-time
      - (recovery in milliseconds)

- no free lunch
  - attainment and maintenance of survivability consumes resources in
    - development,
    - operation,
    - evolution
  - cost and risk analysis to manage resources wisely
Introduction

- Usage/Intrusion Requirements
  - testing must demonstrate
    » correct performance of essential and non-essential system services
    » survivability of essential services under intrusion
    » “How does one do this?”
  - but this depends totally on the system’s use
    » use of usage scenarios derived from usage models
  - usage models
    » are developed from usage requirements
    » they specify usage environments and scenarios of system use
  - usage requirements for essential and non-essential services must be defined in parallel with system and survivability requirements
Introduction

- Usage/Intrusion Requirements (cont.)
  - relationship between legitimate and intrusion use
  - intruder may engage in scenarios beyond legitimate scenarios
    » but may use legitimate usage
Introduction

- Development Requirements
  - stringent requirements on system development and testing practices
  - inadequate functionality and software errors can have devastating effects (provide opportunities for intrusion)
  - sound engineering practices are required
  - this also holds for legacy and COTS software components
Development Requirements (cont.)

- Some example requirements for survivable-system development and testing practices:
  
  For some you will say: Yeah right! - How big is the system?!

  @#$%

  » Precisely specify the system’s required functions in all possible circumstances of system use.
  
  » Verify the correctness of system implementations with respect to the functional specifications.
  
  » Specify function usage in all possible circumstances of system use, including intruder use.
  
  » Test and certify the system based on function usage and statistical methods.
  
  » Establish permanent readiness teams for system monitoring,
Introduction

Operation Requirements
- demands for system operation and administration
- defining and communicating survivability policies
- monitoring system use
- response to intrusion
- evolving system functions as needed to ensure survivability under consideration of changes over time in usage environments and intrusion patterns
Introduction

- Evolution Requirements
  - system evolution responds to user requirements for new functions
  - evolution necessary to respond to increasing intruder knowledge of system behavior and structure
  - survivability requires system capabilities to evolve faster than intrusion knowledge
  - rapid evolution prevents intruders from accumulating information about otherwise invariant system behavior
Introduction

- Requirements Definition for Essential Services
  - set of essential services must form viable subsystem
    » complete and coherent

- What if multiple levels of essential services are used?
  » each level must be examined for completeness and coherence
  » requirements needed to define transition to and from different levels

- Provisions for tracing survivability requirements through design, code and test must be established
Introduction

- Requirements Definition for Survivable Services
  - need to define a set of requirements for survivable services
  - four general categories
    » resistance
    » recognition
    » recovery
    » adaptation & evolution
  - these requirements operate in environment with phases of intrusions
    » penetration
    » exploration
    » exploitation
Requirements Definition for Survivable Services (cont.)

- Penetration Phase
  » attempt to gain access through various attack scenarios
  » amateur and professional hackers
  » capitalization on known system vulnerabilities

- Exploration Phase
  » system has been penetrated
  » intruder is exploring internal system organization
  » learns to exploit the access to achieve intrusion objective

- Exploitation Phase
  » performance of operations to compromise system capabilities
Introduction

- Requirements Definition for Survivable Services (cont.)
  - Exploitation Phase (cont.)
    - penetration at user level as stepping stone to find root-level vulnerabilities
    - exploit those vulnerabilities to achieve root-level penetration
    - compromise of the weakest host in network as stepping stone to compromise more protected hosts.

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Survivability Life Cycle Definition

- This discussion is based on section 3 of:

**Survivable Network Analysis Method**

CMU/SEI-2000-TR-013
ESC-TR-2000-013

Nancy R. Mead
Robert J. Ellison
Richard C. Linger
Thomas Longstaff
John McHugh
Waterfall Model

- Model utilizes following steps:
  - Document of system concept
  - Identify of system requirements and analyze them
  - Break the System into Pieces
    » Architectural Design
  - Design Each Piece
    » Detailed Design
  - Code the System Components and Test them Individually
    » Coding, Debugging, and Unit Testing
  - Integrate the Pieces and Test the System
    » System Testing
  - Deploy the System and Operate it
Waterfall vs. Spiral Model

- Shortcomings of Waterfall Model
  - does not quite apply to today’s development realities
    » represents a “linear process in batch-oriented world”
  - missing
    » flexibility
    » robustness
    » risk management capabilities

- Spiral Model
  - “accommodates” activities such as prototyping, reuse, automatic coding as part of the process”
  - very important to us is risk management
  - need to augment spiral model by survivability considerations
Spiral Model

- Overcome limitations of Waterfall Model

Figure 1: A Project Spiral Cycle

[source CMU/SEI-2000-TR-013]
**Specialization of Spiral Model**

**Primary Motivation/Driver:**
- Functionality
- Performance
- Dependability
- Scalability
- ...

**Add** → **Survivability**

**Foundation:**
- Spiral Process Model

**Primary Constraints:**
- Mission
- Organization
- Environment
- Cost
- Schedule
- Knowledge
- Technology
- ...

**Spiral Process Model with survivability added to every activity**

*Figure 2: Specialization of the Spiral Model for Survivability Driver*

[source CMU/SEI-2000-TR-013]
### Table 2: Life-Cycle Activities and Corresponding Survivability Elements

<table>
<thead>
<tr>
<th>Life-Cycle Activities</th>
<th>Key Survivability Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission Definition</td>
<td>Analysis of mission criticality and consequences of failure</td>
<td>Estimation of cost impact of denial of service attacks</td>
</tr>
<tr>
<td>Concept of Operations</td>
<td>Definition of system capabilities in adverse environments</td>
<td>Enumeration of critical mission functions that must withstand attacks</td>
</tr>
<tr>
<td>Project Planning</td>
<td>Integration of survivability into life-cycle activities</td>
<td>Identification of defensive coding techniques for implementation</td>
</tr>
<tr>
<td>Requirements Definition</td>
<td>Definition of survivability requirements from mission perspective</td>
<td>Definition of access requirements for critical system assets during attacks</td>
</tr>
<tr>
<td>System Specification</td>
<td>Specification of essential service and intrusion scenarios</td>
<td>Definition of steps that compose critical system transactions</td>
</tr>
<tr>
<td>System Architecture</td>
<td>Integration of survivability strategies into architecture definition</td>
<td>Creation of network facilities for replication of critical data assets</td>
</tr>
<tr>
<td>System Design</td>
<td>Development and verification of survivability strategies</td>
<td>Correctness verification of data encryption algorithms</td>
</tr>
<tr>
<td>System Implementation</td>
<td>Application of survivability coding and implementation techniques</td>
<td>Definition of methods to avoid buffer overflow vulnerabilities</td>
</tr>
<tr>
<td>System Testing</td>
<td>Treatment of intruders as users in testing and certification</td>
<td>Addition of intrusion usage to usage models for statistical testing</td>
</tr>
<tr>
<td>System Evolution</td>
<td>Improvement of survivability to prevent degradation over time</td>
<td>Redefinition of architecture in response to changing threat environment</td>
</tr>
</tbody>
</table>