MIT ESD Sandia National Laboratories
Massachusetts Institute of Technology
Engineering Systems Division

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Beyond 'Gates, Guards & Guns':

Applying a Systems, Control & Organizational Theory-Based Methodology for Security at Nuclear Facilities

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Outline

What's Wrong?

What We Have Now

What's Missing?

What's Needed?

What New?

What's Gained?

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What's Wrong?

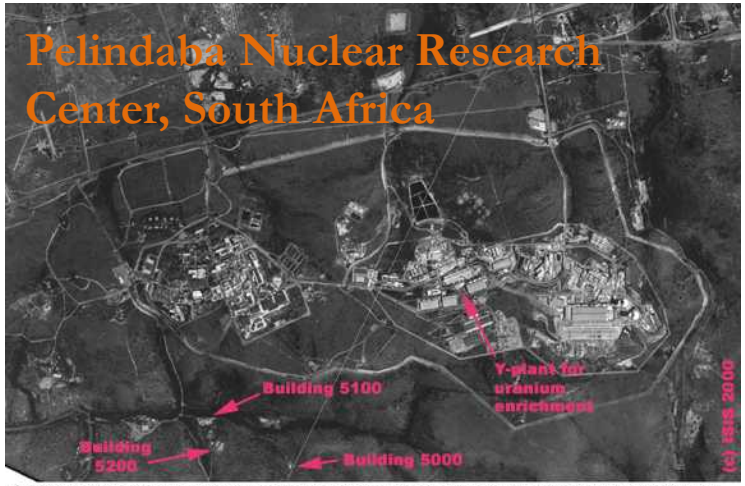
Global **attention**:

- Nuclear Security Summits
- IAEA Security Division
- Terrorist groups/rogue nations

Resource **attention**:

- >$1B spent in U.S.

Operational **attention**?

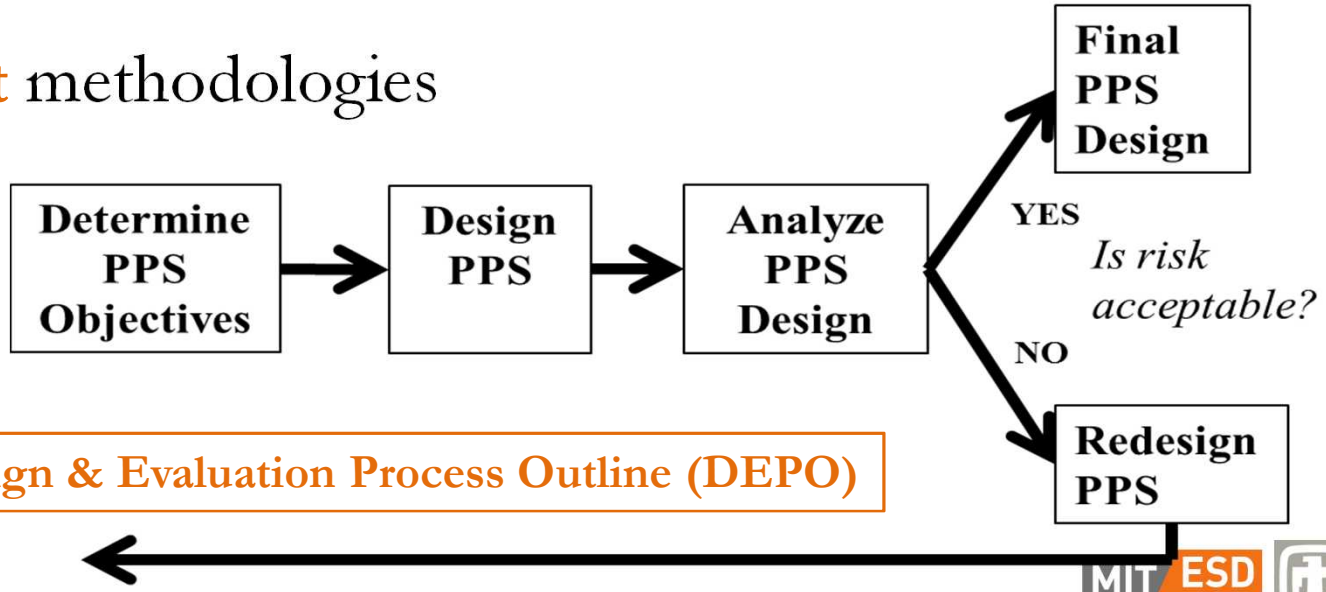


Significant former nuclear weapons related facilities at the Pelindaba-Valindaba Complex, near Pretoria, South Africa. December 1991 KVR-1000 image from www.terraserver.com.

'Every dollar that a facility manager spends on protection is a dollar *not* spent on revenue-generating production' [Bunn 2007]

Today's Approaches Emphasize:

- '**bottom-up**' causality
- '**chain-of-event**' models
- **Probability** (independence & randomness) theory
- **Reliability** (component redundancy & balanced layers) thinking
- **Path dependent** methodologies



Design & Evaluation Process Outline (DEPO)

Today's Security is Challenged By:

- The '**insider**' problem
- **Legacy effects**
- **Complacency**
- Need to define '**security culture**'
- The **long time intervals** between security incidents

Security = protecting the most vulnerable path(???)

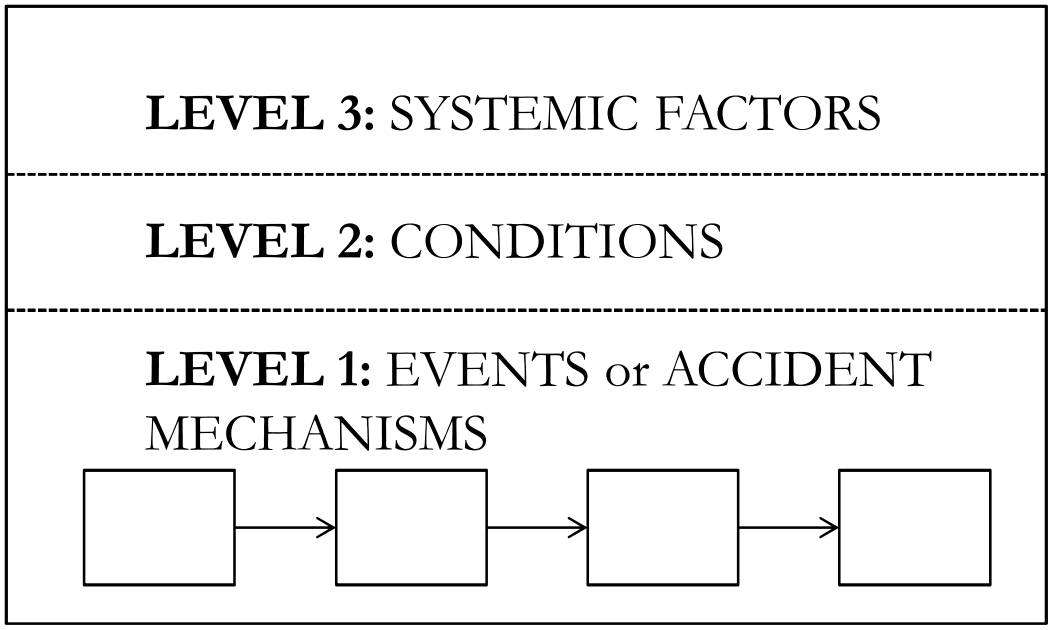
Today's Security is Missing:

- Nuclear facility = **complex, socio-technical system**
- **Security** of system ≠ **reliability** of components
- **Dynamic** & **interactive** complexity
- Rigorous **inclusion** of **organizational/social** aspects

$$\text{Security} = f\left(\begin{array}{c}\textit{System Theory}\\ \textit{Control Theory}\\ \textit{Organization Theory}\end{array}\right)$$

Today's Security Needs: SYSTEM THEORY

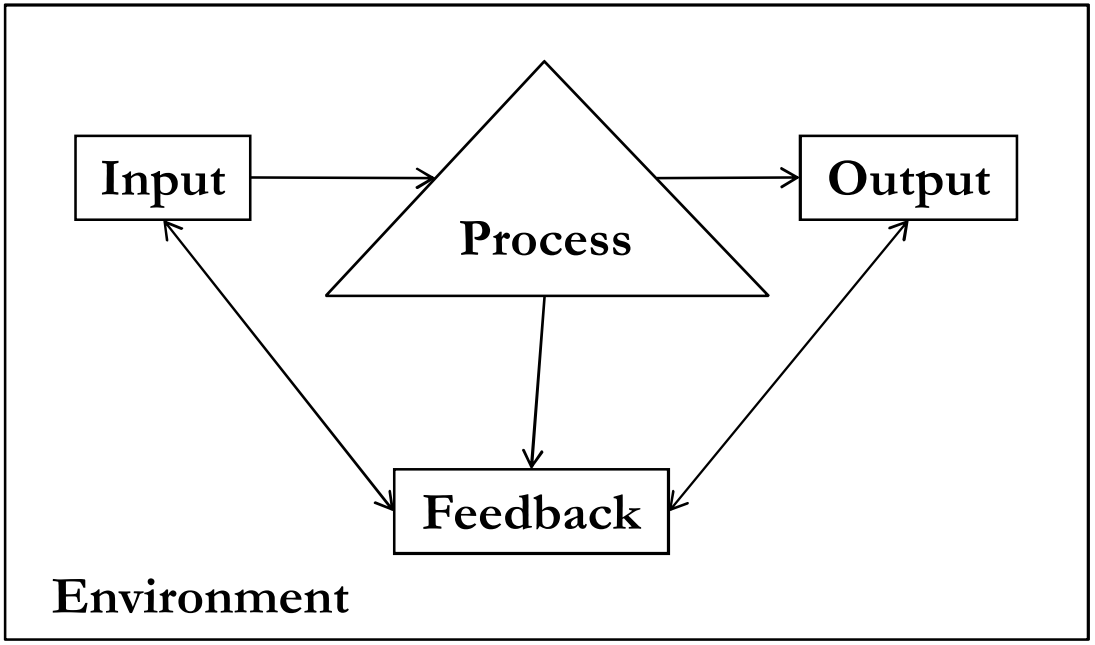
- **Hierarchy**: relationship between levels of complexity
- **Emergence**: irreducible phenomenon



Security = emergent across hierarchical levels

Today's Security Needs: CONTOL THEORY

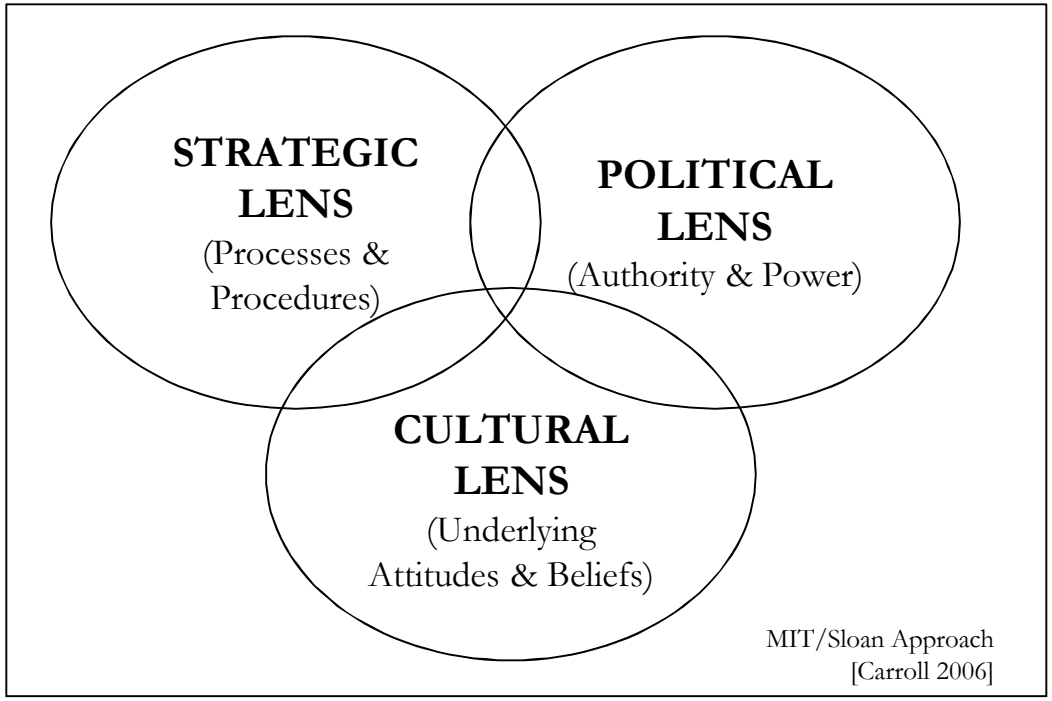
- **Control**: constraints on behavior across levels
- **Communication**: information travel around control loop



Security = communication of control actions

Today's Security Needs: ORGANIZATION THEORY

- **Structuration Theory**: structure emerges from recurrent human action
- **System Dynamics**: non-linear feedback & dynamic complexity



Security = recurrent human actions over time

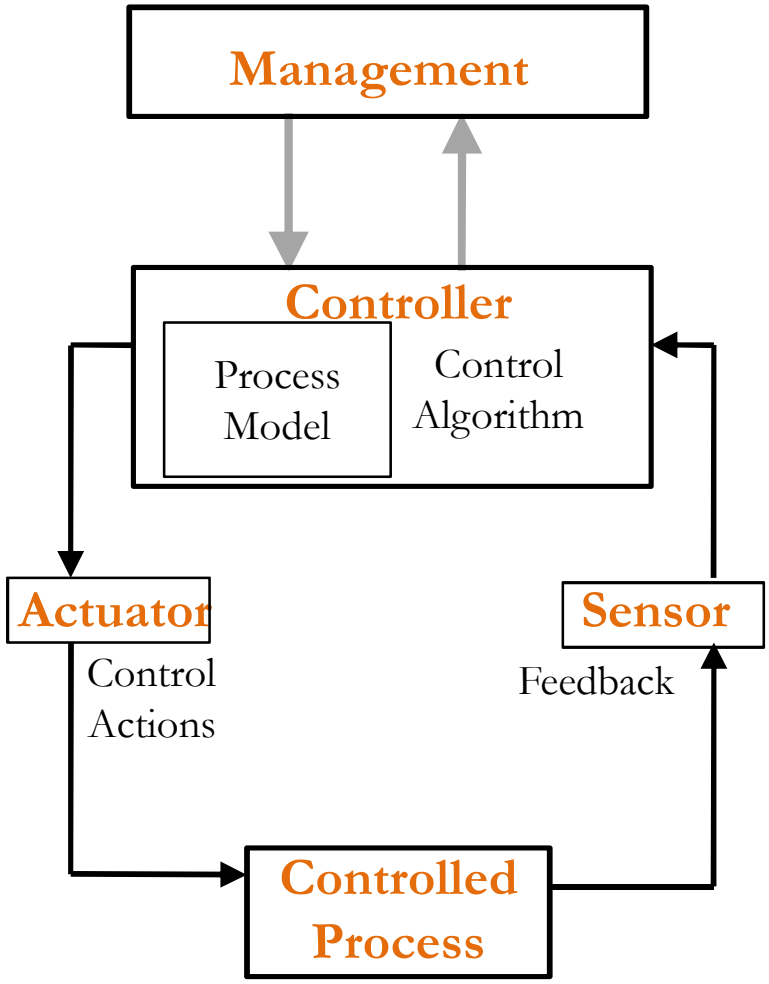
Today's Security Via: STAMP

- **System Theoretic Accident Model & Process** (**STAMP**)
- '**top-down**' causality model for vulnerabilities
- Based on **systems** & **control** theory
- Identify vulnerabilities to **eliminate/minimize insecure system states** (e.g., redesign)
- Includes **organizational considerations** in analysis

Security = eliminating migration of facility into vulnerable or insecure states

Today's Security Via: STAMP

- Define Mission
- Identify Losses
- Identify Vulnerable States
- Derive Security Requirements
- Define Security Control Actions
- Find Security Control Action Violations
- Derive Adversary Actions



STAMP Basic Control Structure

[Leveson, 2012; Thomas 2012]

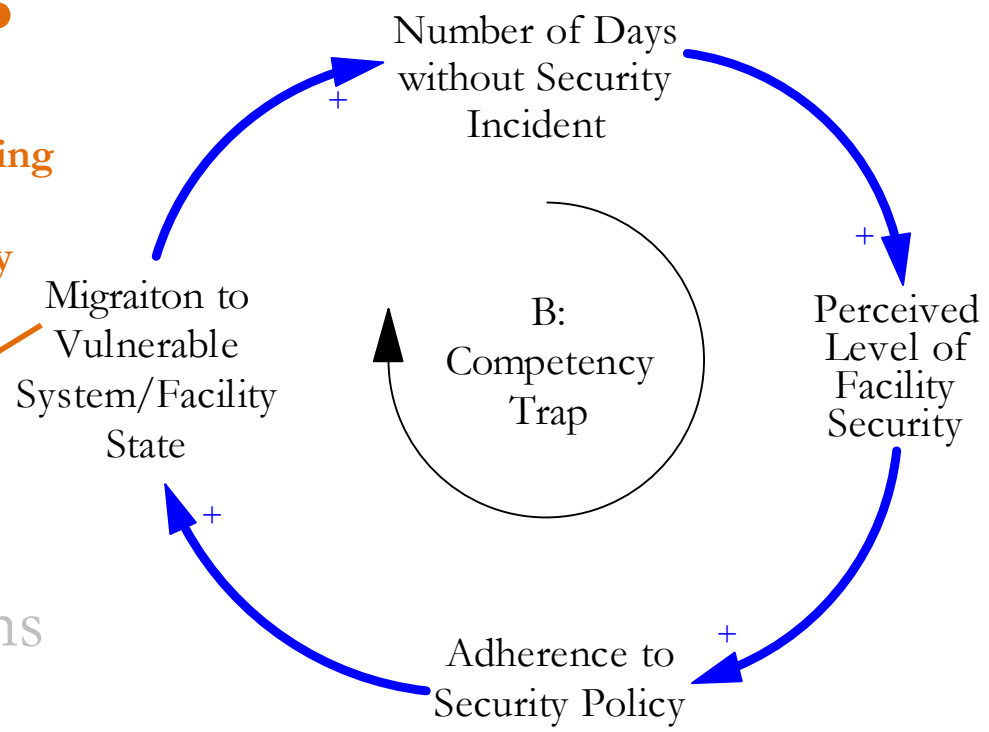
Today's Security Via: STAMP

- Define Mission
- Identify Losses

Detection trap; funding & incentives issues; frequency of security policy changes

- **Identify Vulnerable States**
- Derive Security Requirements
- Define Security Control Actions
- Find Security Control Action Violations
- **Derive Adversary Actions**

'Insider' actions; collusion/coercion; disaffected employee



Today's Security Via: STAMP

- **Higher # vulnerabilities** identified
- **Physical/cyber interaction** vulnerabilities identified
- **Safety/Security/ Safeguards interaction** vulnerabilities identified

Current Approaches	System Attribute	STAMP Approach
Protection of nuclear materials against most vulnerable paths	**Definition of Security**	Maintaining a system state that can protect nuclear materials from loss
Reliability engineering, probability theory	**Basis for Analytical Framework**	Systems theory, system dynamics
Included as initial design condition	**Treatment of Organizational Culture**	Included as an ongoing system attribute
Combinatorial	**Type of Complexity**	Dynamic Interactive

Today's Security Via: STAMP

- Security = **emergent property of a nuclear facility**
- Accounts for dynamic complexity → **dynamic equilibrium**
- **Traceability** between security improvements & vulnerable states
- **Organizational issues** related to vulnerable facility states
- Framework for identifying **component interaction effects**
- Paradigm shift: **preventing security failures** → **enforcing security constraints**

Questions???

"No problem can be solved from the same level of consciousness that created it"

-Albert Einstein