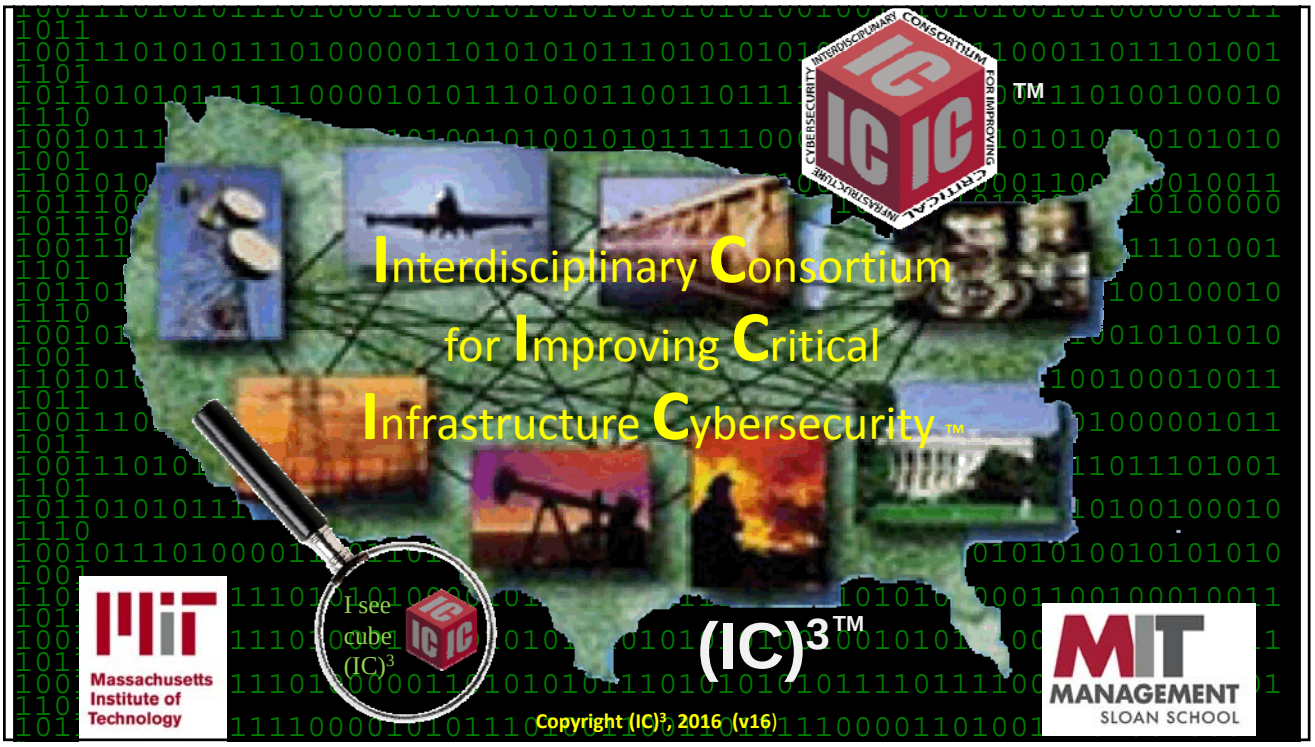

Filling Important Need for Improved Security of Critical Infrastructure

- **Security of conventional information systems is recognized as important …**
  - But still not fully effective (e.g., Target, Sony, HSBC, US OPM, etc.)
- **Security of our Cyber-Physical Infrastructure and IoT …**
  - E.g., computer controlled utilities, home sensors, oil & gas sites, chemical, water, financial services, autonomous vehicles, telecom, infrastructure, etc.

  … is even more important, but much less research has been done.
- **Most research focused on improving hardware and software**
  - Helpful, but …
  - Majority of events (estimates 70-80%) are aided or abetted by insiders
- **Need to address managerial, organizational, and strategic aspects of cybersecurity**

2

Who is this important to? *(Just about Everyone!)*

- **White House Executive Order (2014, 2015, 2016): "… cyber threat to critical infrastructure continues to grow and represents one of the most serious national security challenges we must confront …"**
- **SEC Commissioner Luis A. Aguilar … warned that "boards that choose to ignore, or minimize the importance of cybersecurity oversight responsibility, do so at their own peril …"**

3

Interdisciplinary MIT Team Members

- **Stuart Madnick** – Professor of Information Technologies, **MIT Sloan School of Management** & Professor of Engineering Systems, **MIT School of Engineering**
- **Nazli Choucri** – Professor of Political Science, **MIT School of Humanities and Social Sciences, MIT School of Engineering**
- **David Clark** – Senior Research Scientist in Computer Science and Artificial Intelligence Laboratory (CSAIL)
- **Michael Coden –** Research Affiliate (former member of White House cyber study)
- **Jerrold Grochow** – Research Affiliate (former MIT CIO and member of MITei cyber study)
- **James Kirtley**– Professor of Electrical Engineering, **MIT School of Engineering**
- **Andrew Lo** – Professor of Financial Engineering, **MIT Sloan School of Management**
- **Allen Moulton** – Research Scientist, **MIT School of Engineering**
- **Michael Siegel** – Principal Research Scientist, **MIT Sloan School of Management**
- **Richard Wang** – Principal Research Scientist, **MIT Sloan School of Management**
- **John Williams** – Professor of Civil and Environment Engineering and Engineering Systems, **MIT School of Engineering**
- **Raphael Yahalom -** Research Affiliate, **MIT Sloan School of Management**

4

Current Active $(IC)^3$ Projects

Strategy/Governance
* Board governance of cyber
* Board-level cyber education
* Where does cybersecurity leadership fit in organization

Management

Operations
* Cyber safety: Applying research in accident prevention to cybersecurity
* Lessons learned from studying cyber attacks on Industrial Control Systems (ICS)

Finance
* Impact of cyber risk concerns on innovation
* Cyber risk evaluation & metrics
* Role of cyber insurance in risk mitigation

Technology
* Vulnerability research and the Security workforce
* Evaluating and comparing national cyber frameworks
* Usability vs security

Partnering
* Comparison of international cyber information sharing processes
* Success factors for cybersecurity startups

Organization
* Home of Security: Organizational Cybersecurity Culture
* Bridging IT/OT culture gap
* Framework for types of cyber education throughout organization
* Ethics of Cybersecurity

*** Mature research (papers available)**
*** In-progress research (informal initial results)**
*** Start-up research**

Note: Most projects fit into multiple categories. Only the primary category is shown.

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Examples of $(IC)^3$ Research

- **MIT House of Security:** Techniques to measure perceptions of security in an organization.
- **Cybersafety:** Extend research on accident prevention to prevent cyber events.
- **Vulnerability Research and Workforce:** Enlarge cybersecurity workforce through crowd source methods of, such as "bug bounty" programs, and understand the vulnerability ecosystem.
- **Many Others**: Cyberinsurance, Board of Director Cyber Education, Information Sharing, NIST Framework, Tipping Point Analysis, etc. …

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MIT House of Security
Approach: Survey security attitudes and Gap Analysis

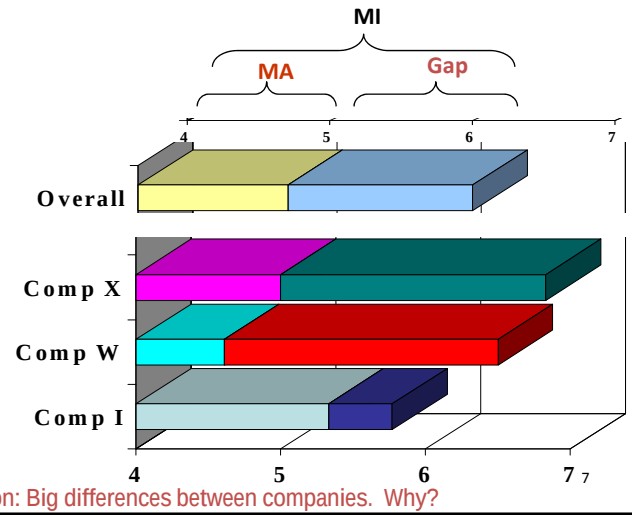
Pilot survey instrument developed.

E.g., Survey Question: In our organization, people are aware of good security practices.

MA = Assessment of "My" organization (5.1)

MI = Importance for "My" organization (6.3)

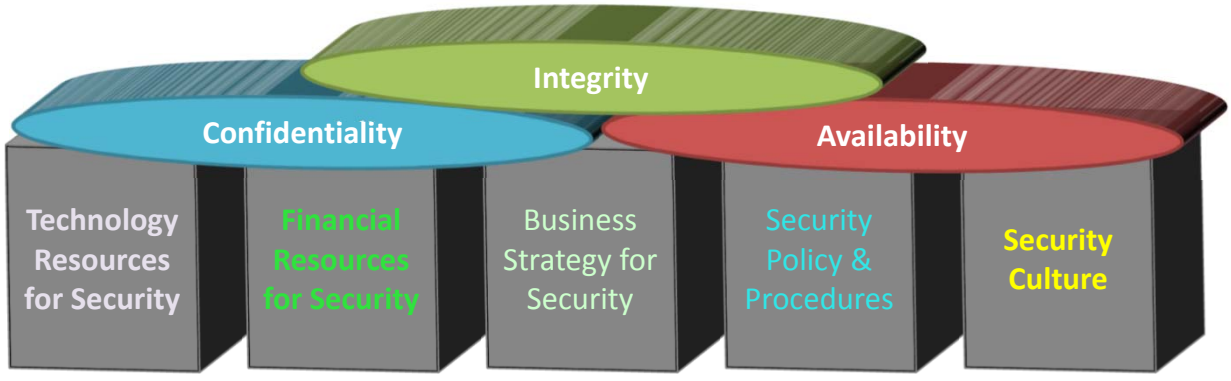
Gap = difference between Assessment and Importance – for "My" organization (1.2)



Observation: Big differences between companies. Why?

7

MIT House of Security Constructs

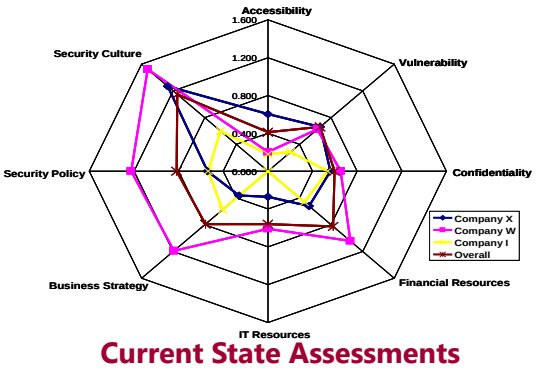


A Fundamental Model for Measuring Cybersecurity Effectiveness

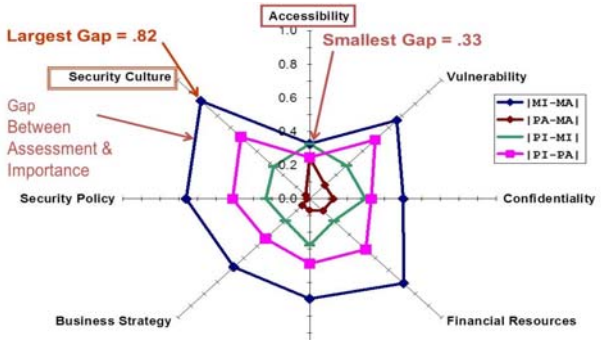
- ***The House of Security has been shown to be able to provide measurements of perceptions, awareness, profile, tier, maturity, and gaps in Cybersecurity.***
- **It will be further developed to provide economic measurements of cyber-risk and the value of Cybersecurity activities allowing a calculation of Cyber-ROI.**

Example Results from Using the MIT House of Security

- Using survey questions we assessed perception of the current state of security in the organization … and the desired state.
- The delta is the measureable gap between desired and actual.



Current State Assessments by Three Companies: Big Differences



Gap Analysis

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Cybersafety: Use of Accident Research to Prevent Cyber Incidents

- **Apply "accident" and safety research to "cyber security" failures.**
- MIT has researched accidents and how to prevent them (including studying NASA problems) for many years.
- We are now treating a cyber incident/event as a type of "accident" and using prior research to identify, understand, and mitigate possible "cyber-hazards."
  - Examples, such as Stuxnet and TJX, have been analyzed.
  - Uncovered vulnerabilities not in previous reports

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Cybersafety Methodology

Key principles:

- **Top-down:**
  - What are you trying to protect / prevent?
- **Based on process model:**
  - There are Processes and Controllers for those Processes, with "sensors" and "actuators"
- **The Processes are Hierarchical:**
  - The Controllers are processes and are controlled by higher level controllers, etc.

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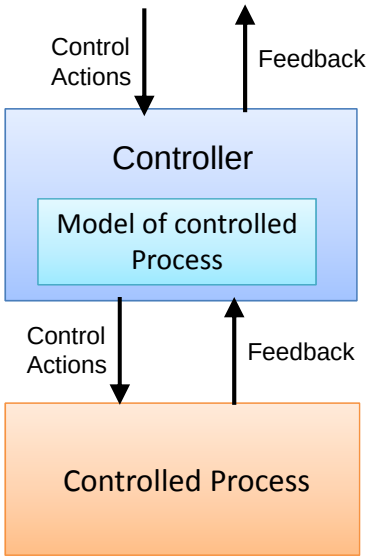
Hierarchical Process Model

Process Model in System Theoretic Accident Process and Modeling (STAMP) can be applied Hierarchically



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NEWS

TJX data breach: At 45.6M card numbers, it's the biggest ever

Mar 29, 2007

It eclipses the compromise in June 2005 at CardSystems Solutions

By Jaikumar Vijayan FOLLOW

Computerworld | Mar 29, 2007 1:00 PM PT

After more than two months of refusing to reveal the size and scope of its data breach, TJX Companies Inc. is finally offering more details about the extent of the compromise.

In filings with the U.S. Securities and Exchange Commission yesterday, the company said 45.6 million credit and debit card numbers were stolen from one of its systems over a period of more than 18 months by an unknown number of intruders. That number eclipses the 40 million records compromised in the mid-2005 breach at CardSystems Solutions and makes the TJX compromise the worst ever involving the loss of personal data.

MORE LIKE THIS

Theft of 45.6M Card Numbers Largest Heist Yet

Update: Retail breach may have exposed card data in four countries

Stolen TJX data used in Florida crime spree

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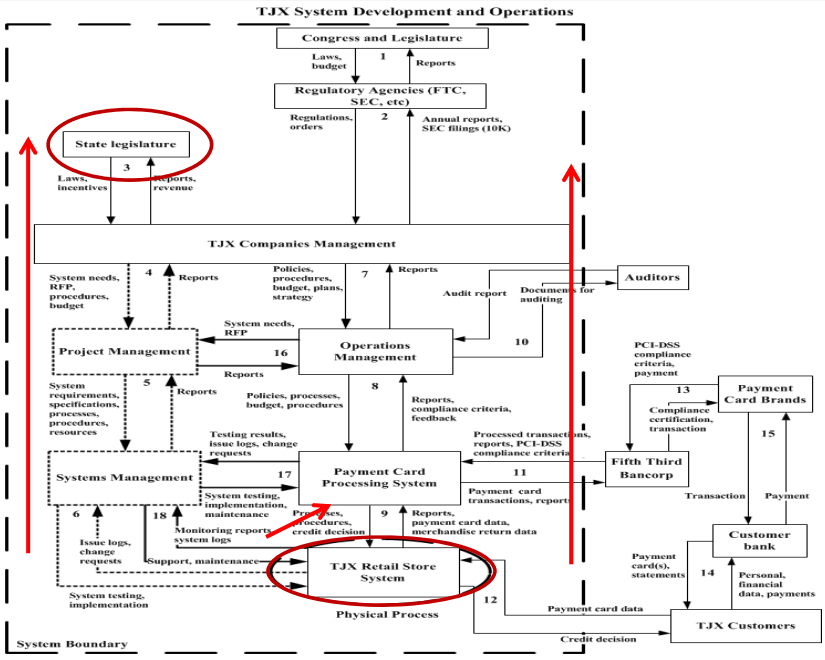
Hierarchical Control Structure



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Analysis of Higher Levels of the Hierarchical Safety Control Structure

1. Safety-Related Responsibilities:

a. Payment card **data is encrypted**.
b. TJX **systems should be PCI-DSS compliant**. (Compliance with PCI-DSS is required by retailers accepting credit cards).
c. Provide **data retention process/procedures**.
d. Systems pass **rigorous testing**.

4. Process Model Flaws:

a. Belief that processors compliance with PCI-DSS implies compliance by TJX.
b. Inadequate understanding of full scope of PCI-DSS

2. Context:

TJX **not in compliance** with PCI-DSS.

3. Unsafe Decisions and Control Actions:

a. Inadequate **compliance** with PCI-DSS.
b. Retained **more customer data** than needed/for **longer periods** than required.
c. Inadequate **testing** of systems/lack of awareness of PCI-DSS.
d. Payment data **briefly stored and then transmitted unencrypted** to the bank.
e. Visa **issued a warning** to processor that TJX needed to be fully compliant, but (a) it had **limited influence on TJX and (b)** Visa **had already granted TJX suspended fines** until 2008

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Dynamics and Migration to a High-Risk State

Leveson: "most major accidents are a result of migration of a system to a high-risk state over time. Understanding the dynamics of migration will help in redesigning the system."

1. **A major change contributing to the cyber-attack was TJX's move from wired to wireless networking (Wi-Fi) in 2000 in a short span of one year.**
   a. Initially cyber security risk was low because vulnerabilities were unknown to everyone – experts, businesses, **and hackers**.
   b. TJX decided against upgrading to a more secure encryption algorithm for cost reasons.
2. **Flaws in managerial decision making process.**
   a. **Ease of recall bias** where recent experiences strongly influence the decision (i.e., no break-ins so far.)

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Dynamics and Migration to a High-Risk State

3. **Confirmation trap** is a decision maker's tendency to favor information that confirms existing beliefs and discount contradicting information.

"My understanding is that we can be PCI-compliant without the planned FY07 upgrade to WPA technology for encryption because most of our stores do not have WPA capability without some changes. WPA is clearly best practice and may ultimately become a requirement for PCI compliance sometime in the future. I think we have an opportunity to defer some spending from FY07's budget by removing the money for the WPA upgrade, but would want us all to agree that the risks are small or negligible."

a. Above is a message from CIO to his staff, requesting agreement on his belief that cyber security risk is low. -- a majority of his staff agreed.

b. This confirmation trap led to postponing upgrades.

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Some Recommendations resulting from Analysis

1. According to PCI Security Standards Council, compliance is a business issue requiring management attention and need to **integrate PCI-DSS requirements within appropriate components on development and operations parts of the control structure**.
2. **PCI-DSS not fully adequate**.
   a. Data must be encrypted when sent over a public network, **but not when transmitted within TJX**.
   b. PCI-DSS did not mandate using stronger encryption WPA until 2006, even though WPA was available in 2003.
3. Building a safety culture at TJX including a **dedicated executive role** with cyber security responsibilities.

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Comparison of Results from FTC and CTC Investigations and Cybersafety STAMP/CAST Analysis

No.	Recommendation	CPC	FTC	STAMP/CAST
1	**Create an executive level role for managing cyber security risks.**	No	*	**Yes**
2	**PCI-DSS integration with TJX processes.**	No	No	**Yes**
3	**Develop a safety culture.**	No	No	**Yes**
4	**Understand limitations of PCI-DSS and standards in general.**	No	No	**Yes**
5	**Review system architecture.**	No	No	**Yes**
6	**Upgrade encryption technology.**	Yes	No	*
7	**Implement vigorous monitoring of systems.**	Yes	No	*
8	**Implement information security program.**	No	Yes	*

FTC = Federal Trade Commission; **CPC** = Canadian Privacy Commission

* = Indicates recommendations that are close to STAMP/CAST based analysis but also has differences.

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Vulnerability Detection and Reduction

- Heard of “Bug Bounty” Programs?
- MIT is studying methods of vulnerability detection, such as “bug bounty” programs, using techniques such as System Dynamics modeling
  - Over 100 firms offer public bug bounty programs, recently United Airlines
  - Facebook has had over $3.5 million in payouts
  - HackerOne runs bug bounty programs for about 72 companies
  - Represents “defensive capability” and some insight to “offensive capability”
- Can determine best types of vulnerability discovery and detection techniques, including “bug bounty,” open source, and other approaches.

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Example: "Hack the Pentagon"

- The DOD had paid **$5 million** over three years to one vendor, which found less than **10 vulnerabilities**.
- In "Hack the Pentagon": 1,400 eligible ethical hackers (aka as "white hats") were invited, 250 of them found at least one vulnerability.
- Of these, **138 were found** to be "legitimate, unique, and eligible for a bounty," said Secretary Carter. … Cost? About **$150,000**.
- Also, it frees up the US military's own cyberspecialists "to spend more time fixing them than finding them. The pilot showed us one way to streamline what we do to defend out networks and correct vulnerabilities more quickly."

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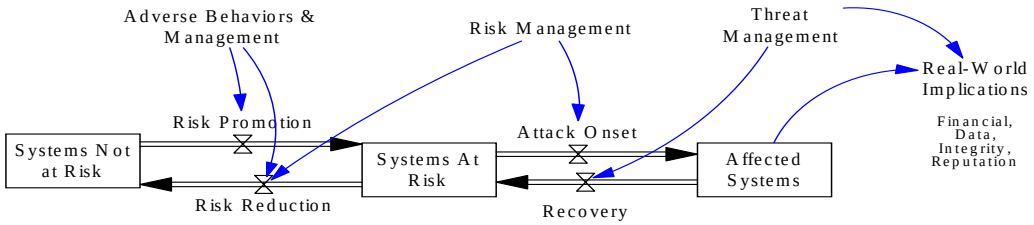
Dynamics of Threats and Resilience
(using System Dynamics modeling)

How did breaches (threats) occur? *

67% were aided by significant errors (of the victim)

64% resulted from hacking

38% utilized Malware



How are security and threat processes (resilience) managed? *

Over 80% of the breaches had patches available for more than 1 year

75% of cases go undiscovered or uncontained for weeks or months

* Verizon Data Breach Report

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Some Findings

- Solving security problems "upstream" is more effective than fixing them "downstream."
- Models help understand the security issues in patching and software release dynamics
- Understanding the tools and techniques of finding vulnerabilities helps to improve security
- Understanding the researcher/hacker/security workforce will help with defense
- All organizations can learn from bug bounty programs

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Why Join $(IC)^3$?

- Existing organizations are trying to address today's threat and plan for future threats, but:
  - "The CSO/CISO is too busy bailing water to plug the holes in the boat"
- $(IC)^3$ is focusing MIT's uniquely qualified interdisciplinary faculty and researchers on the fundamental principles of cybersecurity applied to Critical Infrastructure:
  - "Enabling the CSO/CISO to plug the holes in the boat"
  - Creating tools to
    - Strategically develop measureable, cost effective, cybersecurity strategies
    - Implement Cybersafety awareness and culture change
    - A confidential academic forum in which to benefit from the experiences of CSO/CISOs from multiple sectors

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Operation of $(IC)^3$

- The day-to-day operation of $(IC)^3$ is managed by the Director of $(IC)^3$ with the support of the $(IC)^3$ Associate Directors.
- The $(IC)^3$ Advisory Board, in consultation with the Director of $(IC)^3$, will determine the research focus areas for each year.
- The $(IC)^3$ faculty working with full-time MIT research staff and graduate students, often in cooperation with Member organizations, will conduct the research.
- $(IC)^3$ will organize and conduct two research topic-specific workshops each year.
- $(IC)^3$ will organize and conduct its Annual Conference, covering the wide range of its research topics, each year.

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Types of Sponsors and Benefits *

- **Members**: $35,000 if three year commitment or $45,000 if one year commitment
  - Send 2 people to annual conference and 2 workshops per year
  - Access to research in the MIT-$(IC)^3$ research database[1]
- **Partners**: $120,00 per year – commitment for 3 years (can be 1 year for first year) Includes all items above plus:
  - Ability to suggest research areas
  - Ability to re-distribute select research content to existing clients and customers[1] Ability to contact designated faculty via telephone
- **Patrons**: $450,000 per year – commitment for 3 years (can be 1 year for first year) Includes all items above plus:
  - Ability to suggest research projects and refinements, be considered for inclusion
  - A dedicated faculty contact, with monthly consultations
  - One on-site faculty presentation to the organization's governing board

* Details on additional benefits contained in the Sponsorship Agreement

[1] Subject to 3rd party rights and bearing appropriate legends

From more information, go to http://ic3.mit.edu

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See http://ic3.mit.edu or contact Stuart Madnick smadnick@mit.edu or Michael Siegel msiegel@mit.edu or Michael Coden mcoden@mit.edu