CADA:
CyManII Attack-Defense Annex

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Agenda

- Project goals
- CADA data models and analysis
- Risk scenario: Network attacks and incidence response
- Closing remarks

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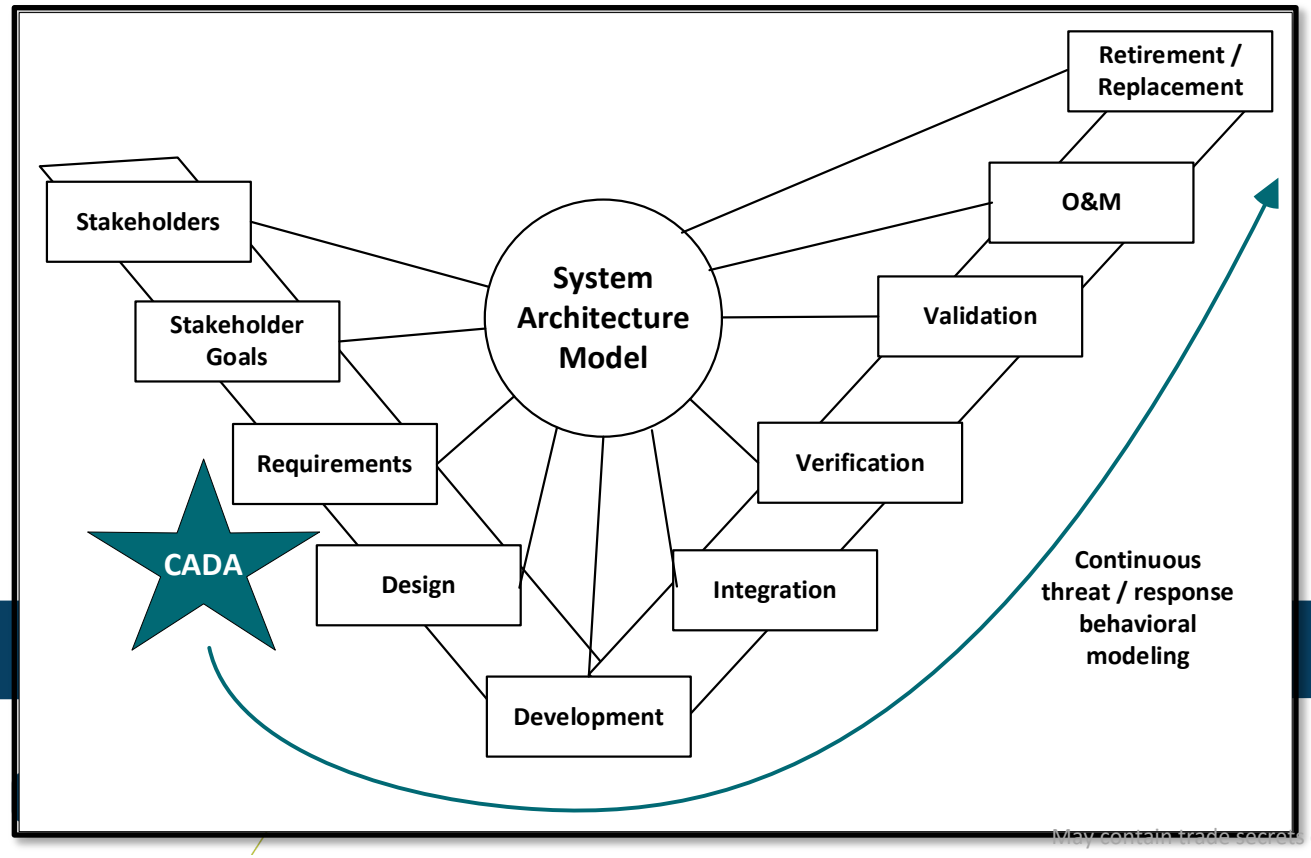
CADA Goals

SN-3	DEVELOP THE SECURITY ASPECTS OF OPERATIONAL AND OTHER LIFE CYCLE CONCEPTS
SN-3.1	Define a representative set of scenarios to identify all required protection capabilities and security measures that correspond to anticipated operational and other life cycle concepts.
SN-3.2	Identify the security-relevant interaction between users and the system.

Stakeholder Needs (SN-3) from [NIST 800-160 Vol. 1]



- **Characterize** security throughout the SDLC
- **Visualize** security risks within system context as it evolves
- **Develop** behavioral models
- **Demonstrate** impacts on control
- **Analyze** behaviors using formal methods
- **Identify** design tradeoff costs
- **Open-Source** CADA

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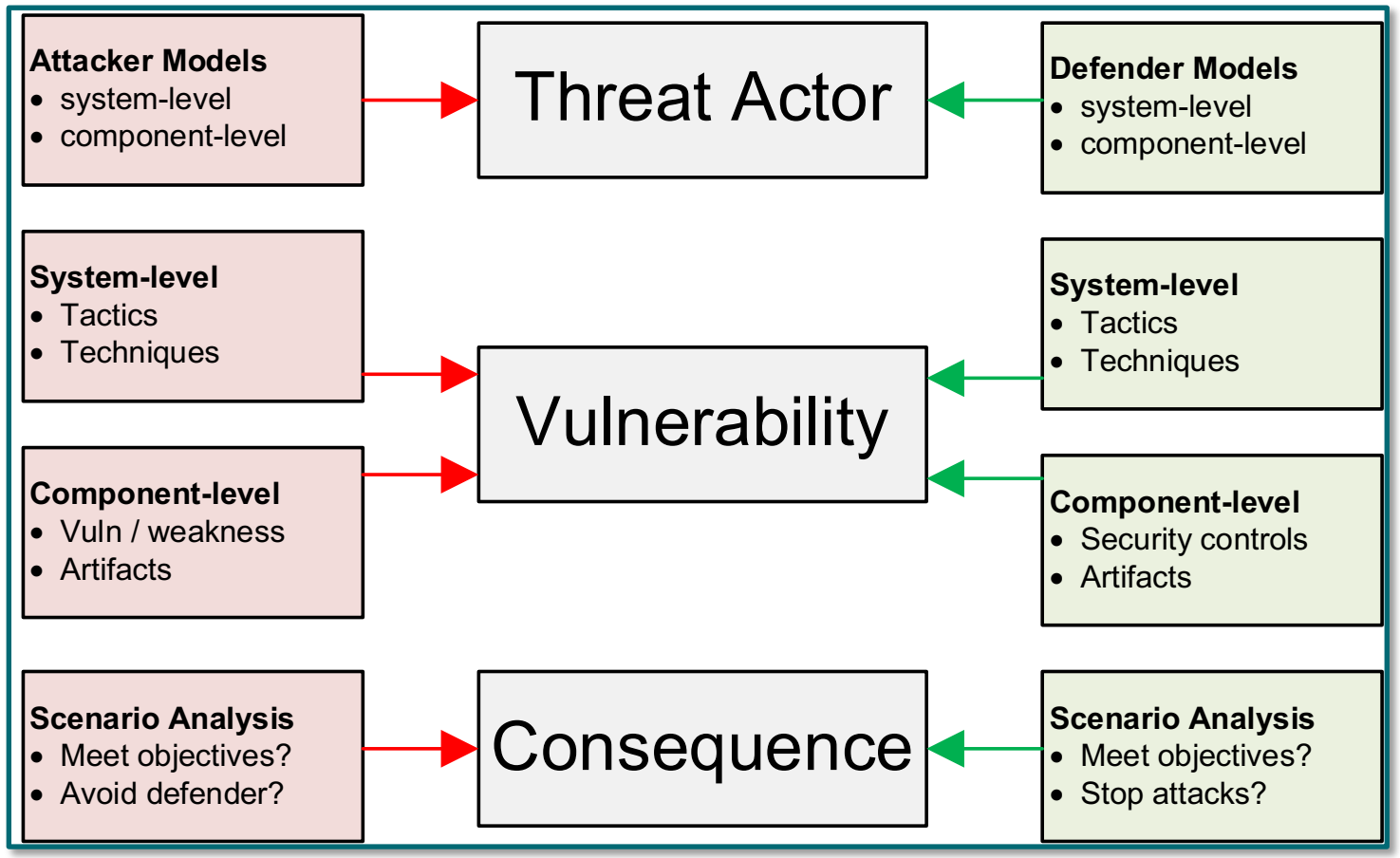
Risk Analysis with CADA

CADA:

- Behavioral data models
- Security risk analysis
- Define realistic attack and response scenarios

Core analytical engines:

- AGREE [AGREE Github]
- Safety Annex [Stewart et. al]



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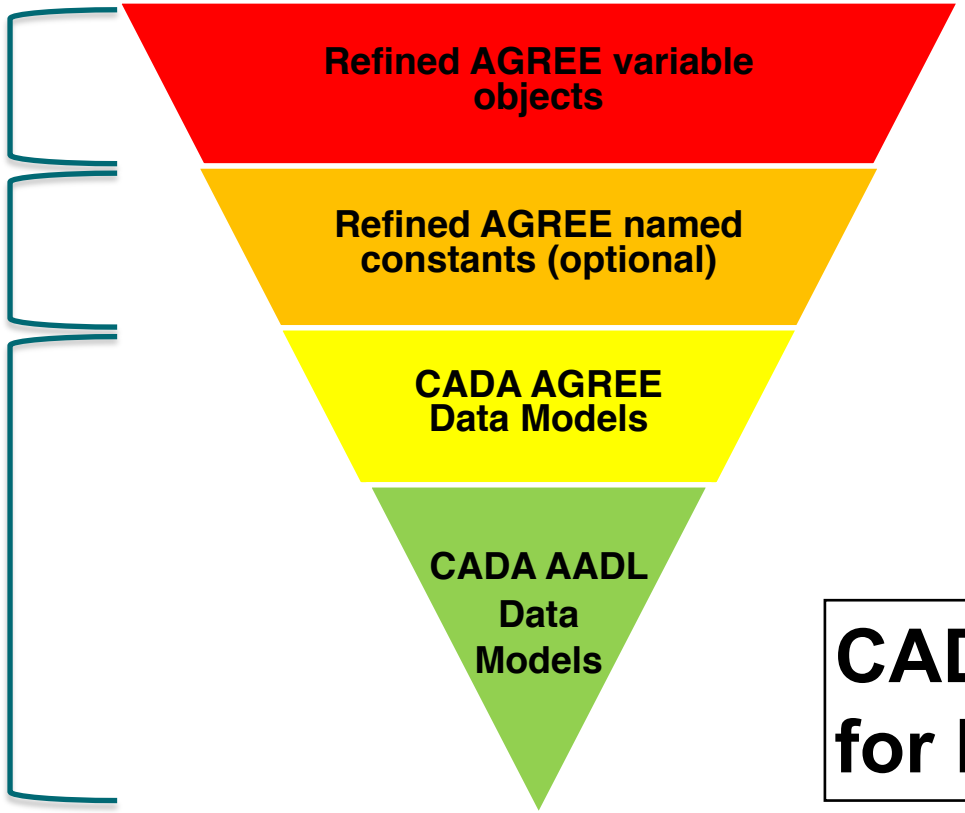
CADA Data Modeling and Analysis In AGREE

Interactions via AGREE statements, CADA nodes, and Safety Annex

Based on system architecture & reqs

Base CADA models



CADA object structure for behavioral analysis

NOTE: we include the above triangle at the top of the next four slides

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CADA AADL Data Models

Data models for attackers and defenders

- [Rochetto & Tippenhauer]

Category	Name	A/D	Type	Possible Values
Knowledge	[Off/Def]_Knowledge_Int	AD	Integer	[0-100]
	Physical_[Off/Def]_Knowledge_Int	AD	Integer	[0-100]
	Network_[Off/Def]_Knowledge_Int	AD	Integer	[0-100]
	Software_[Off/Def]_Knowledge_Int	AD	Integer	[0-100]
	Component_Knowledge_Int	AD	Integer	[0-100]
	Protocol_Component_Knowledge_Int	AD	Integer	[0-100]
	Source_Code_Component_Knowledge_Int	AD	Integer	[0-100]
	Credentials_Component_Knowledge_Enum	AD	enum	none, user, administrator, SYSTEM_access, remote_desktop_users, root, any
Resource	Distance_Resource_Enum	AD	enum	none, far, near, physicalaccess, any
	Manpower_Resource_Enum	AD	enum	low, medium, high
	[Off/Def]_Tools_Resource_Enum	AD	enum	basic, intermediate, advanced
	Financial_Resource_Int	AD	Integer	[0-1000000]
	Effort_Resource_Enum	AD	enum	low, medium, high
Psychology	Off_Aim_Psych_Enum	A	enum	knowledge, manipulation, disrupt, damage
	Def_Aim_Psych_Enum	D	enum	none, confidentiality, integrity, availability, all
	[Off/Def]_Physical_Sec_Aim_Psych_Enum	AD	enum	none, confidentiality, integrity, availability, all
	[Off/Def]_Virtual_Sec_Aim_Psych_Enum	AD	enum	none, confidentiality, integrity, availability, all
	Periodicity_Psych_Enum	AD	enum	once, anytime, continuous
	Determination_Psych_Enum	AD	enum	first_attempt, several_attempts, untiring
	Honesty_Psych_Enum	A	enum	malicious, benign
	Camouflage_Psych_Enum	AD	enum	visible, stealthy, invisible
	Off_Strategy_Psych_Enum	AD	enum	random, brute_force, structured
	Def_Strategy_Psych_Enum	D	enum	random, monitor, investigate, evict

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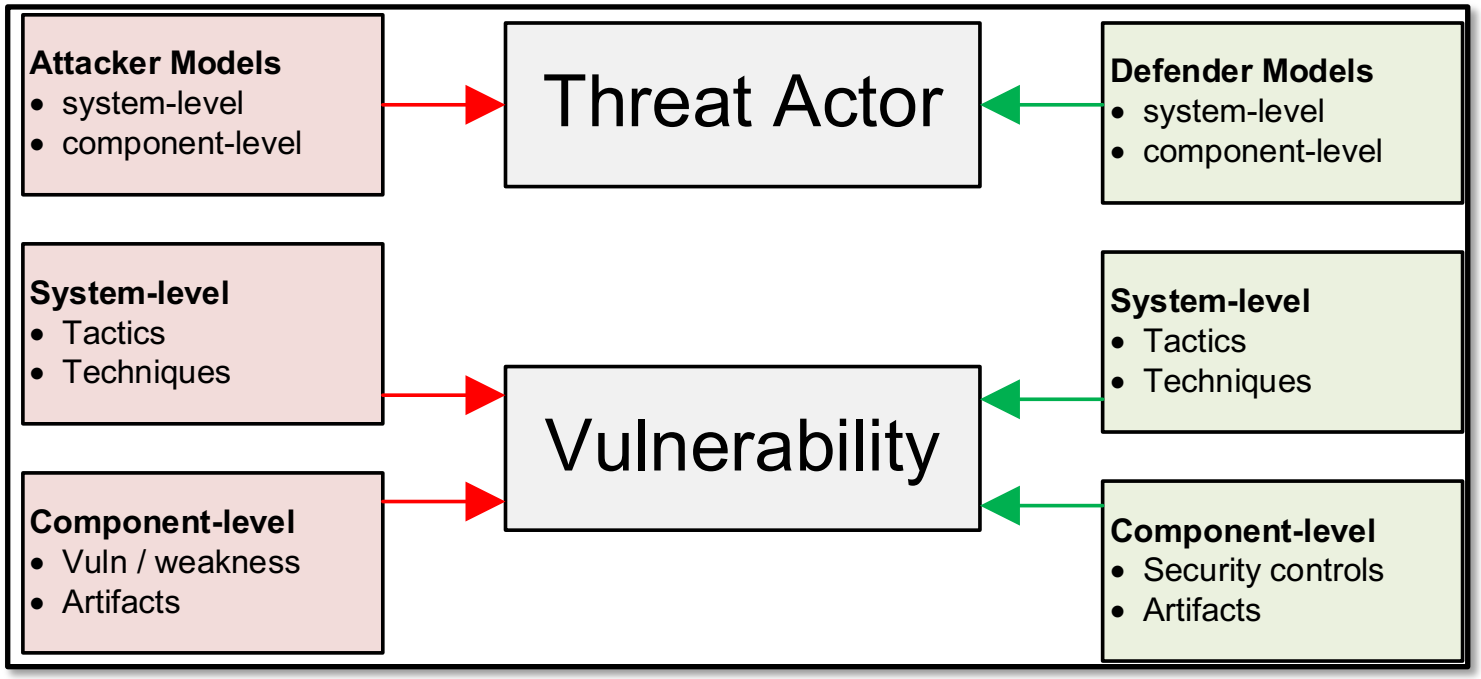
CADA AGREE Data Models



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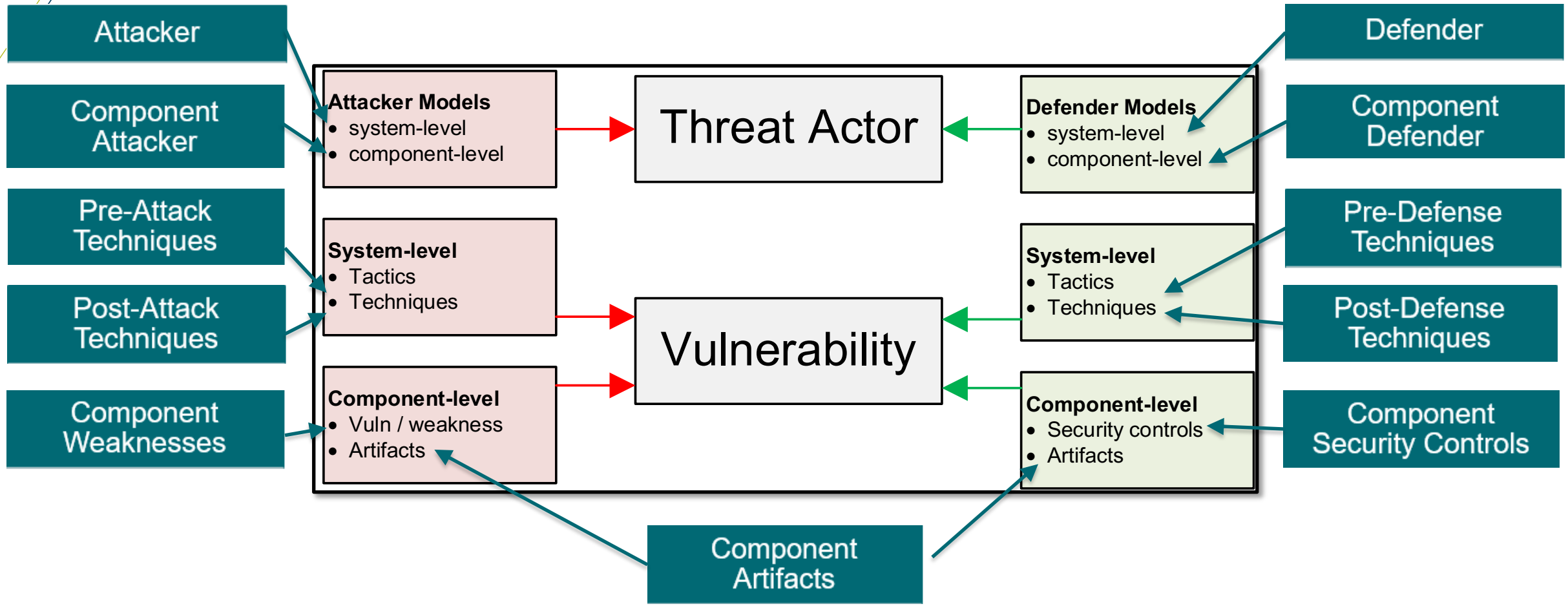

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Refined AGREE Named Constants

- **Optionally refine** the CADA AGREE Data Models using named constants with **actual values**
  - Standards
  - Models
  - Domain experts
  - Best practice
  - etc.
- Refinements **specific to the system or organization**

Attacker

- Nation State
- Insider Threat
- Penetration Tester

Defender

- Incidence Response Team
- Security Engineering
- Physical Security

Attack Techniques

- [MITRE ATT&CK®]
- [MITRE CAPEC]

Defense Techniques

- [MITRE D3FEND™]

Component Weaknesses

- [MITRE CVE®]
- [MITRE CWE™]

Component Security Controls

- [NIST 800-53 Rev. 5]

Component Artifacts

- MITRE D3FEND™ Digital Artifact Ontology [MITRE D3FEND]

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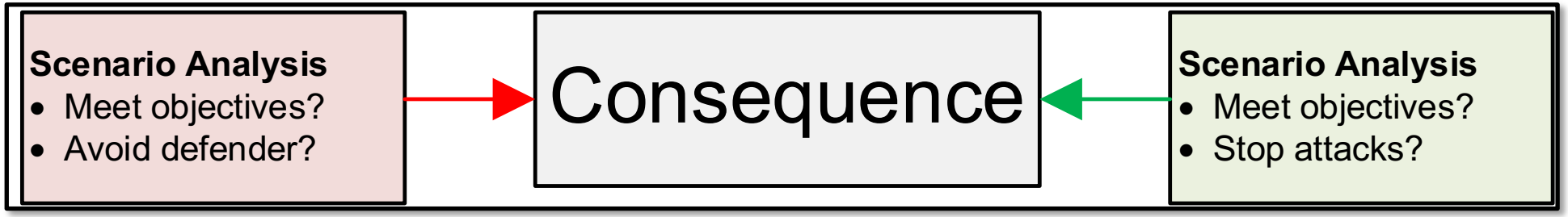
Refined AGREE Variable Objects



- **Analysis** should match perceived and actual real-world conditions
  - **AGREE** and **Safety Annex**
  - **CADA Nodes**
  - **Domain expertise**
  - **Notional process flow**

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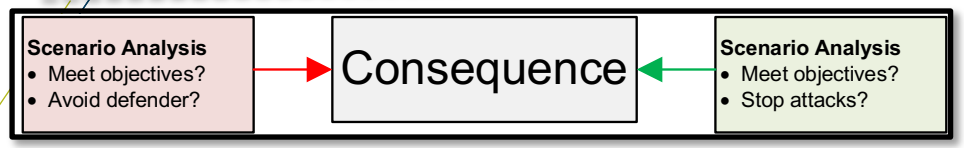
Refined AGREE Variable Objects



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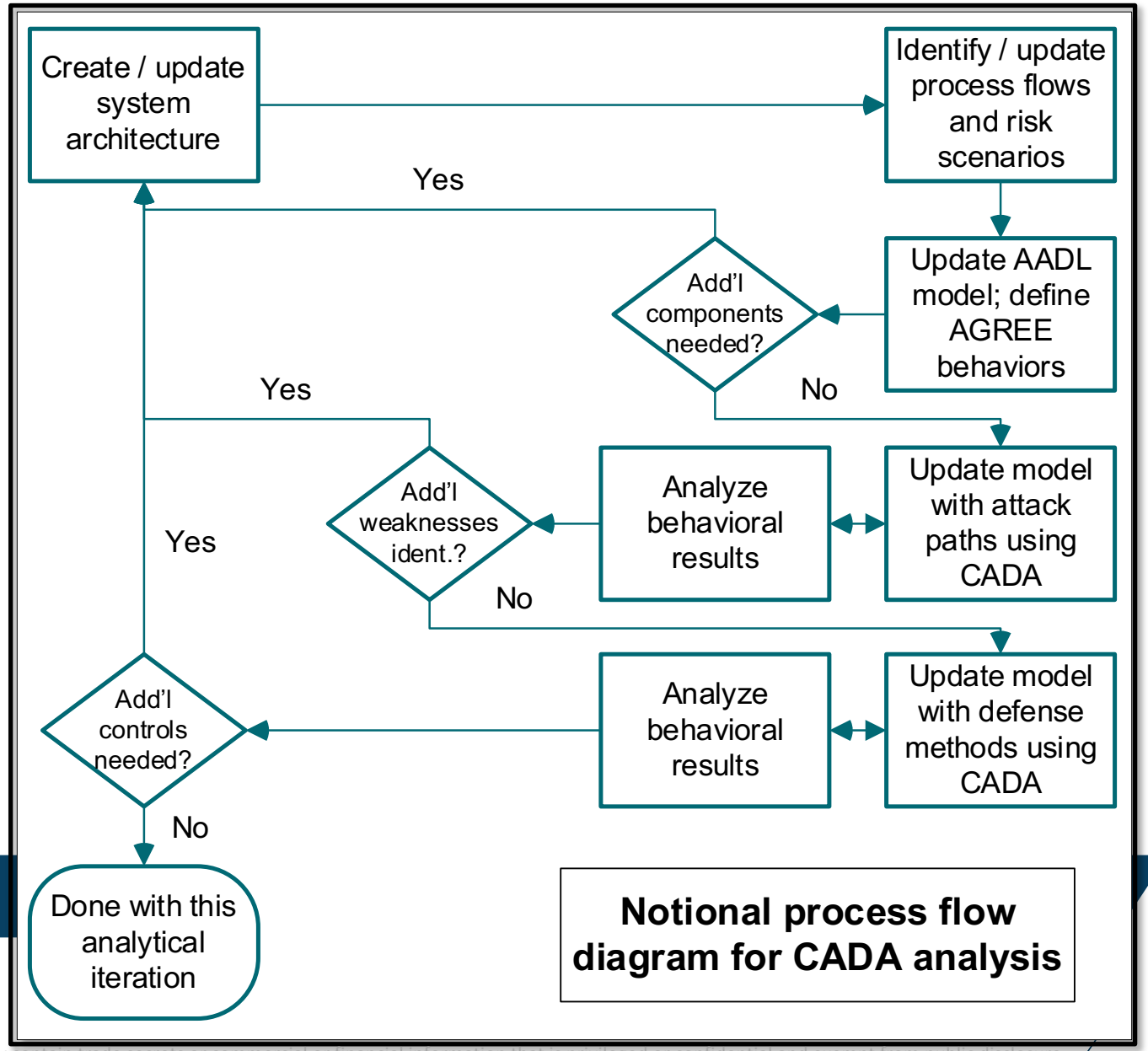

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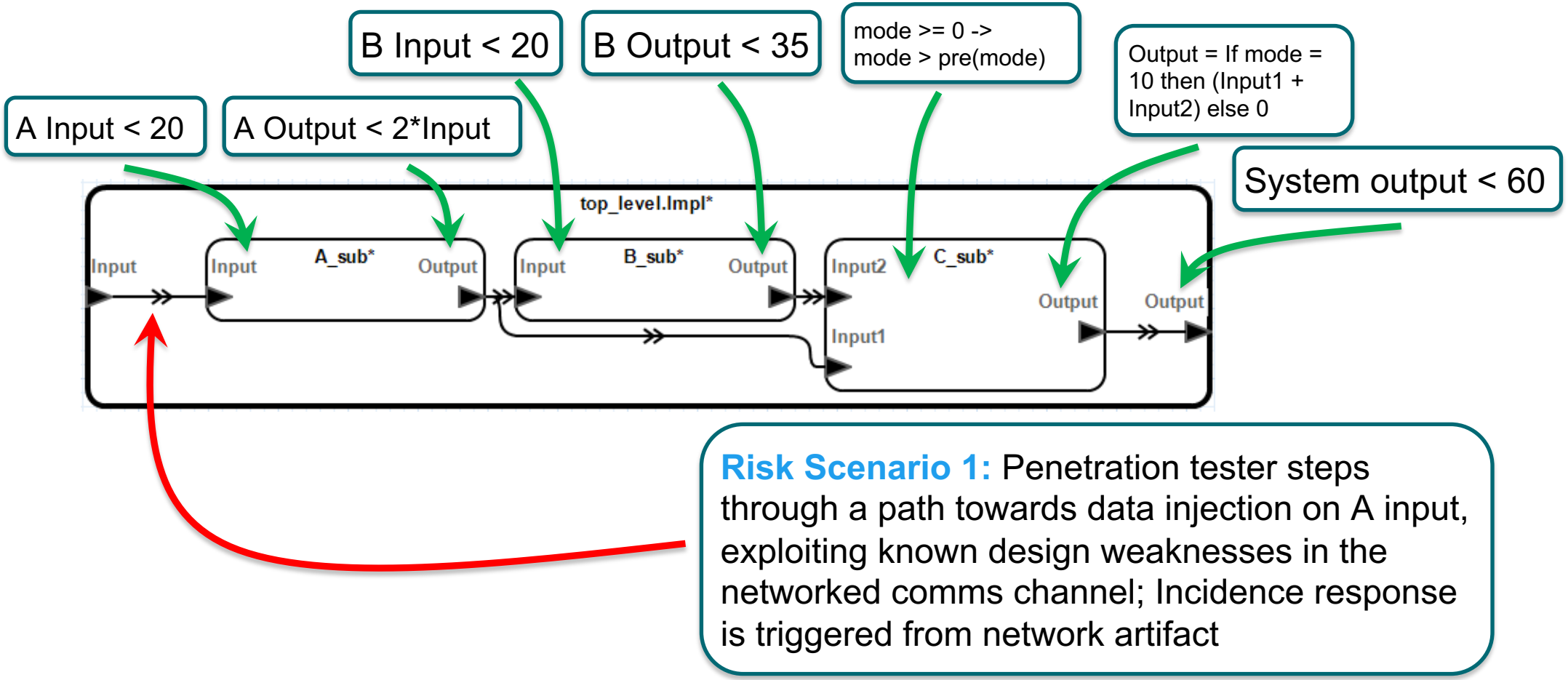
Toy Model Example System Risk Scenario 1



Risk Scenario 1: Penetration tester steps through a path towards data injection on A input, exploiting known design weaknesses in the networked comms channel; Incidence response is triggered from network artifact

NOTE: enhanced from AGREE and Safety Annex toy models for CADA example

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Risk Scenario 1 – Network Attack on System Input

Top-level AGREE Annex:

```
annex agree {**

    eq mode : int;
    assume "System input range " : if A_CWE_77_fail then Input = 100 else Input < 10;
    guarantee "mode is always positive" : mode >= 0;
    guarantee "System output range" : Output < 60;

    --------------
    --Attacker
    --------------
    eq attacker : Attack_AGREE_Models::AD001_ATTACKER = Attacker_AGREE_Types::A003_PENETRATION_TESTER;
    --------------
    --Attacks on A
    --------------
    eq attacker_A : Attack_AGREE_Models::AD001_ATTACKER = (attacker ->
        if A_CWE_200_ud = 1 then
            CADA_Nodes::Adapt_Attacker_From_Weakness(
                prev(attacker_A, attacker),
                Weakness_AGREE_Types::CWE200_EXPOSURE_OF_SENS_INFO
            )
        else if A_CWE_77_ud = 1 then
            CADA_Nodes::Adapt_Attacker_From_Weakness(
                prev(attacker_A, attacker),
                Weakness_AGREE_Types::CWE77_COMMAND_INJECTION
            )
        else prev(attacker_A, attacker)
    );
```

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Attack Results

Property	Result
Verification for top_level.Impl	4 Invalid, 9 Valid
Contract Guarantees	4 Invalid, 4 Valid
A_sub assume: A input range	Invalid (1s)
B_sub assume: B input range	Invalid (1s)
Subcomponent Assumptions	Invalid (1s)
mode is always positive	Valid (3s)
System output range	Invalid (1s)
eq attacker : AD001_ATTACKER	Valid (1s)

	A	B	C	D	E
1	**Step**	0	1	2	3
2					
3	**A_sub**				
4	A_sub..ASSUME.HIST	TRUE	TRUE	TRUE	FALSE
5	A_sub.CWE_77_Present	TRUE	TRUE	TRUE	TRUE
6	A_sub.CWE_200_Present	TRUE	TRUE	TRUE	TRUE
7	A_sub.Input	0	0	0	100
8	A_sub.Output	-1	-1	-1	200
9					
10	**B_sub**				
11	B_sub..ASSUME.HIST	TRUE	TRUE	TRUE	FALSE
12	B_sub.Input	-1	-1	-1	200
13	B_sub.Output	0	0	0	35
14					
15	**C_sub**				
16	C_sub..ASSUME.HIST	TRUE	TRUE	TRUE	TRUE
17	C_sub.Input1	-1	-1	-1	200
18	C_sub.Input2	0	0	0	35
19	C_sub.Output	0	0	0	235
20	C_sub.mode	0	8	9	10
21					
22					
23	A_CWE_77	FALSE	FALSE	TRUE	TRUE
24	A_CWE_77_Present	TRUE	TRUE	TRUE	TRUE
25	A_CWE_77_fail	FALSE	FALSE	FALSE	TRUE
26	A_CWE_77_ud	0	0	1	2
27	A_CWE_77_ud_sp	TRUE	FALSE	TRUE	TRUE
28	A_CWE_200	FALSE	TRUE	TRUE	TRUE
29	A_CWE_200_Present	TRUE	TRUE	TRUE	TRUE
30	A_CWE_200_ud	0	1	2	3
31	A_CWE_200_ud_sp	TRUE	TRUE	FALSE	TRUE
32	A_sub assume: A input range	TRUE	TRUE	TRUE	FALSE
33	B_sub assume: B input range	TRUE	TRUE	TRUE	FALSE
34	Input	0	0	0	100
35	Output	0	0	0	235

Response analysis:
Exploit CWE-200 ->
Exploit CWE-77 -> A's input changes which cascades through to system output to complete attack path

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Risk Scenario 1 – Defensive Response 1

Top-level AGREE Annex:

```
--------------
--Defender
--------------

eq defender : Defend_AGREE_Models::DD001_DEFENDER = Defender_AGREE_Types::D001_INCIDENCE_RESPONSE_TEAM;

--------------
--Defense of A
--------------

--A Defender
eq defender_A : Defend_AGREE_Models::DD001_DEFENDER = defender ->
    if (A_D3_CAA and A_D3_CAA_ud = 1) then
        CADA_Nodes::Adapt_Defender_From_Technique(
            prev(defender_A, defender),
            Defend_Technique_AGREE_Types::D3_CAA_CONN_ATTEMPT_ANALYSIS_POST
        )
    else if (A_D3_ITF and A_D3_ITF_ud = 1) then
        CADA_Nodes::Adapt_Defender_From_Technique(
            prev(defender_A, defender),
            Defend_Technique_AGREE_Types::D3_ITF_IN_TRAFFIC_FILTER_POST
        )
    else if (A_D3_BDI and A_D3_BDI_ud = 1) then
        CADA_Nodes::Adapt_Defender_From_Technique(
            prev(defender_A, defender),
            Defend_Technique_AGREE_Types::D3_BDI_BROADCAST_DOM_ISO_POST
        )
    else prev(defender_A, defender);
```

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Defense Results

Property	Result
Contract Guarantees	5 Invalid, 10 Valid
A_sub assume: A input range	Invalid (1s)
B_sub assume: B input range	Invalid (1s)
Subcomponent Assumptions	Invalid (1s)
mode is always positive	Valid (20s)
System output range	Invalid (1s)
System A response has not occurred	Invalid (2s)
System A defense not monitoring	Valid (2s)

Response analysis:

- Attack was still successful before defender could respond to bypassed network security controls
- Failure for “System A response has not occurred” check means that the defender did respond to attacker’s events
- Success for “System A defense not monitoring” check means that the defender was always monitoring the system

Question: How can we prevent this traffic injection attack from occurring in the first place?

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Risk Scenario 1 – Defensive Response 2

System A AGREE Annex:

```
--------------
--Defender
--------------

eq defender : Defend_AGREE_Models::DD001_DEFENDER = Defender_AGREE_Types::D002_SECURITY_ENGINEERING;

--------------
--Defense of A
--------------

--A Defender
eq defender_A : Defend_AGREE_Models::DD001_DEFENDER = defender ->
    if (A_D3_MAN and A_D3_MAN_ud = 1) then
        CADA_Nodes::Adapt_Defender_From_Technique(
            prev(defender_A, defender),
            Defend_Technique_AGREE_Types::D3_MAN_MESSAGE_AUTH_POST
        )
    else prev(defender_A, defender);
```

1

2

Defense Results

Property	Result
✔ Contract Guarantees	16 Valid
✔ A_sub assume: A input range	Valid (46s)
✔ B_sub assume: B input range	Valid (46s)
✔ Subcomponent Assumptions	Valid (46s)
✔ mode is always positive	Valid (44s)
✔ System output range	Valid (46s)
✔ System A response has not occurred	Valid (47s)
✔ System A defense not monitoring	Valid (2s)

Response analysis:

- Traffic injection attack fails when Input data is signed and authenticated ☺
- Defender was monitoring throughout the scenario for signs of attack

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Contributions

- **Introduced CyManII Attack-Defense Annex (CADA)**
  - Provides attack-defense data model
  - Pentest and mitigate attacks early in SDLC
  - Offers risk scenarios that span SDLC and evolve with system
- **CADA's generality**
  - Based on testing, CADA is extendable to all system models that leverage AGREE / Safety Annex
  - Similar data models may be derived to support other modeling languages
  - Intent to open source
- **Email Contact**: FIRST <dot> LAST <at> cymanii <dot> org

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