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AI Grid Sentinels and the Future of Modern Control Room Operations

Andy Reiman and Todd Hay
Pacific Northwest National Laboratory



U.S. DEPARTMENT of ENERGY BATTELLE

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Adaptive AI Agents (AAIA) Overview

- **Vision** – Agentic AI Supports Power Grid Control Room Operations
- **Project Type / Duration** – PNNL EED Lab-Directed R&D in FY26
- **Expected Benefits**



Process More Information During Events

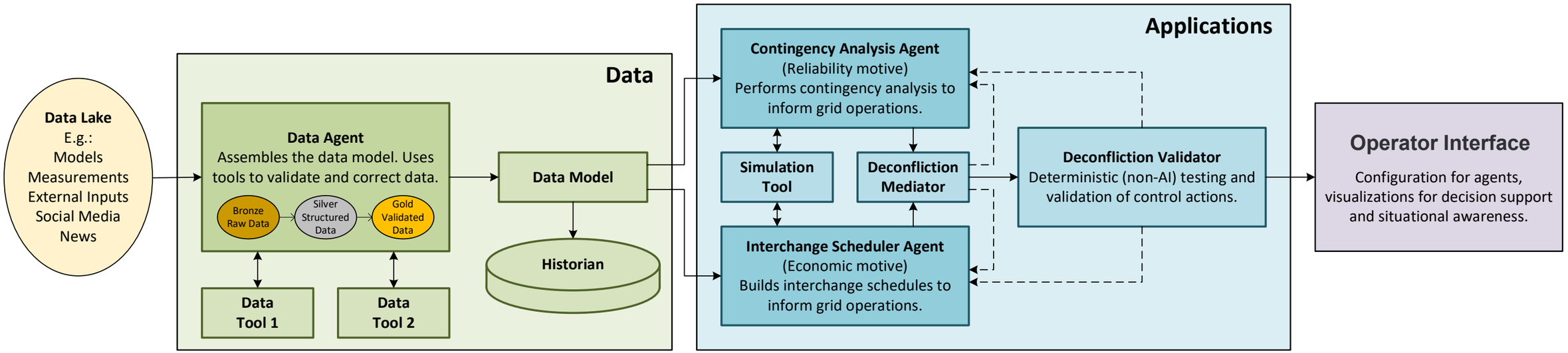
Improve Grid Security Posture



Increase Event-Response Efficiency

Track Multiple Objectives for Novel Insights

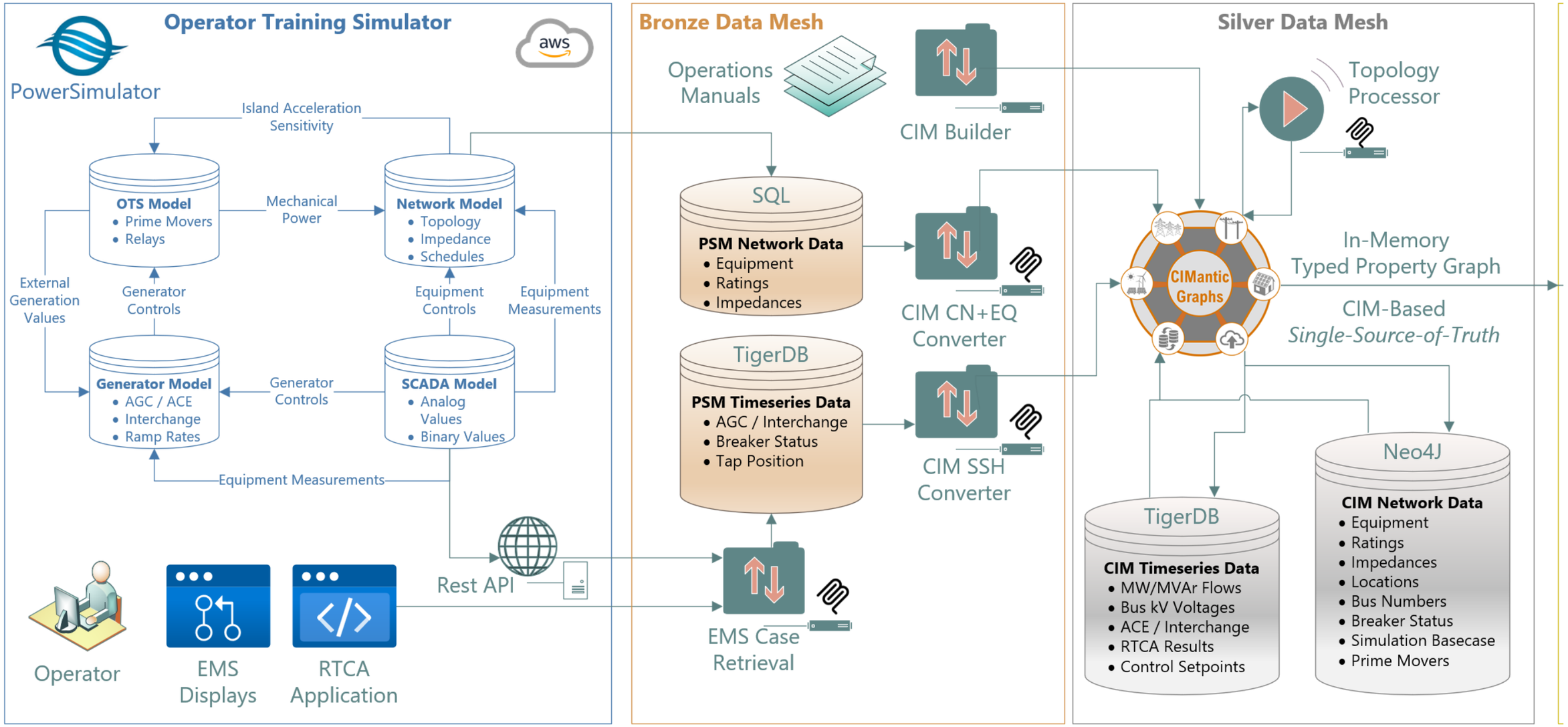
Project Architecture



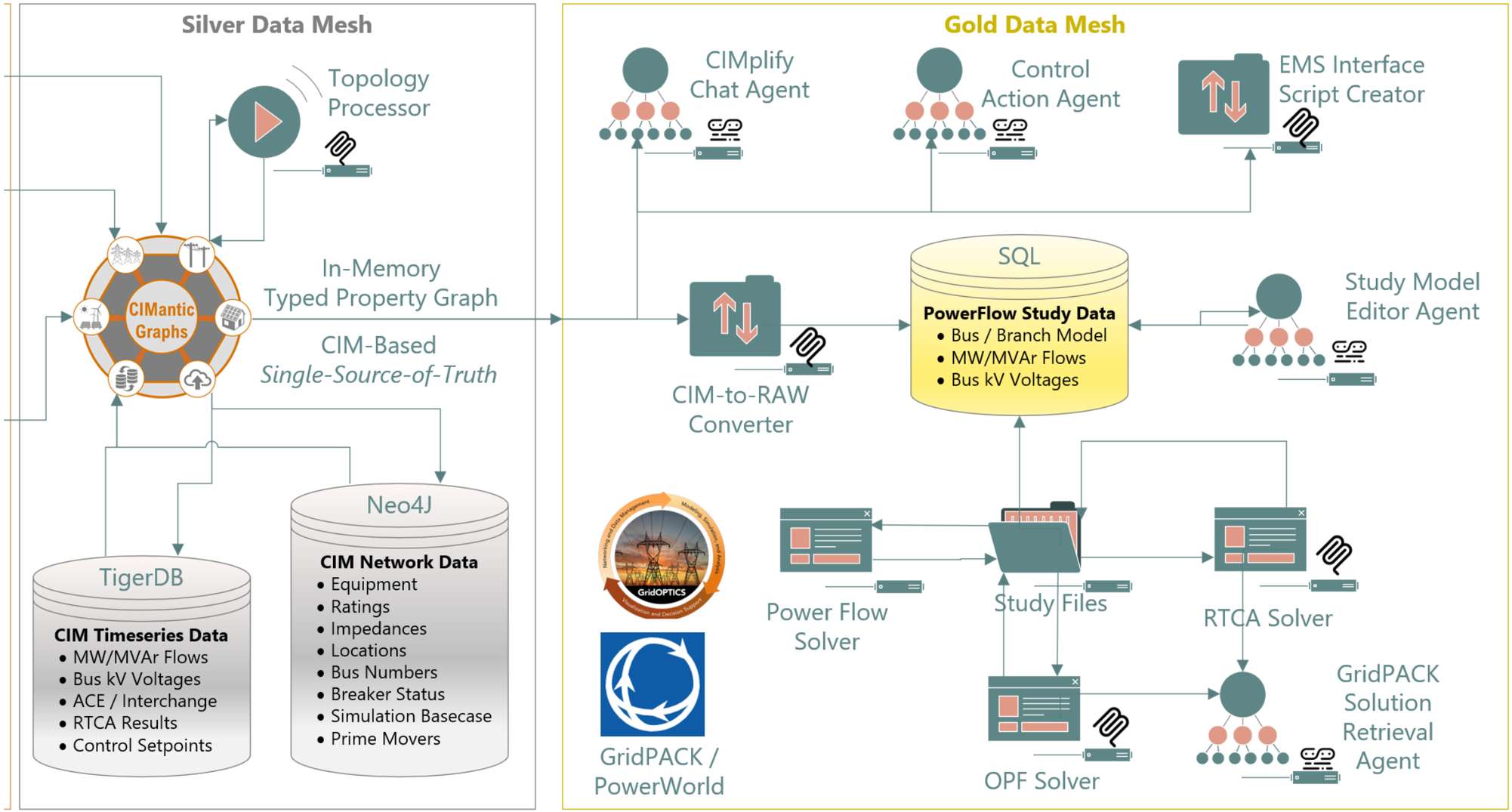
Infrastructure

Compute – AWS · **LLMs** – AI Incubator · **Assured AI** – Principles / Techniques

Thrust 1: Data Mesh for EMS Applications

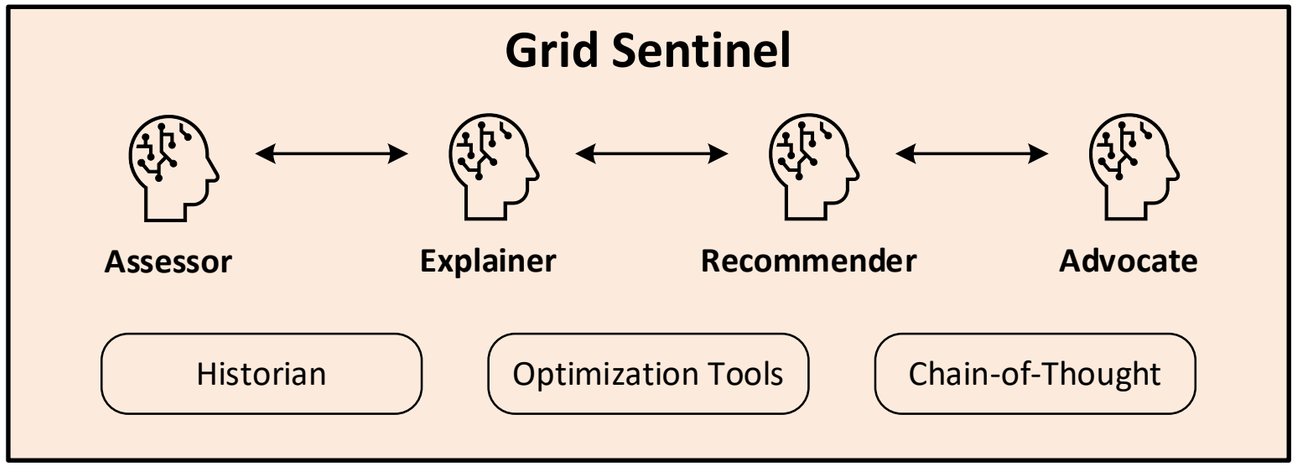


Thrust 1: Data Mesh for Agents



Thrust 2: Grid Sentinels

- Sentinels monitor the grid with an eye on a specific operating objective.
- Sentinels can provide situational awareness, context on demand, action recommendations, and can participate in deconfliction.
- The Security and Efficiency Recommenders are prototype Grid Sentinels.



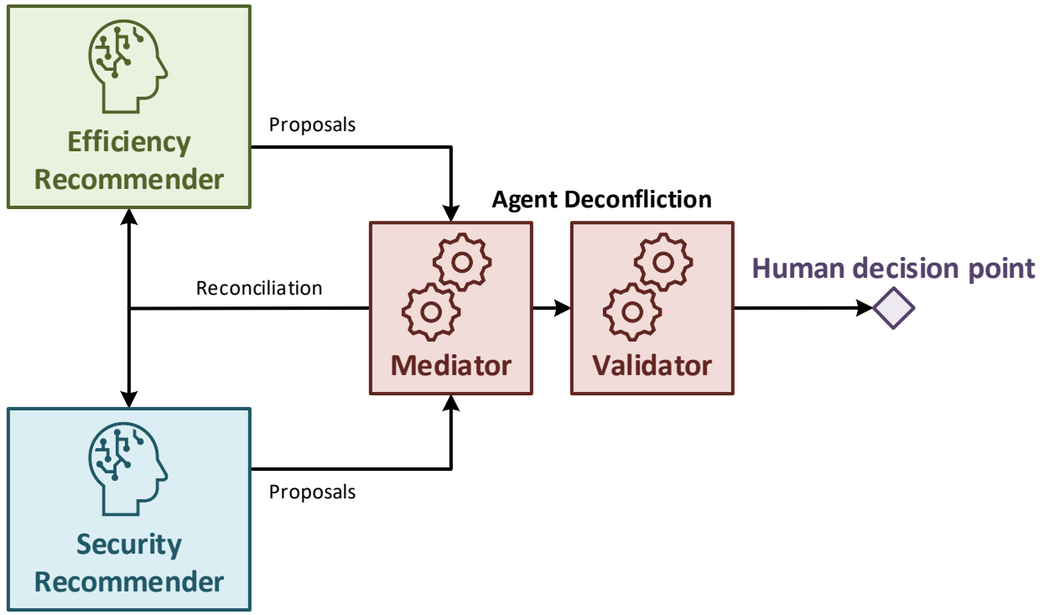
Efficiency Recommender

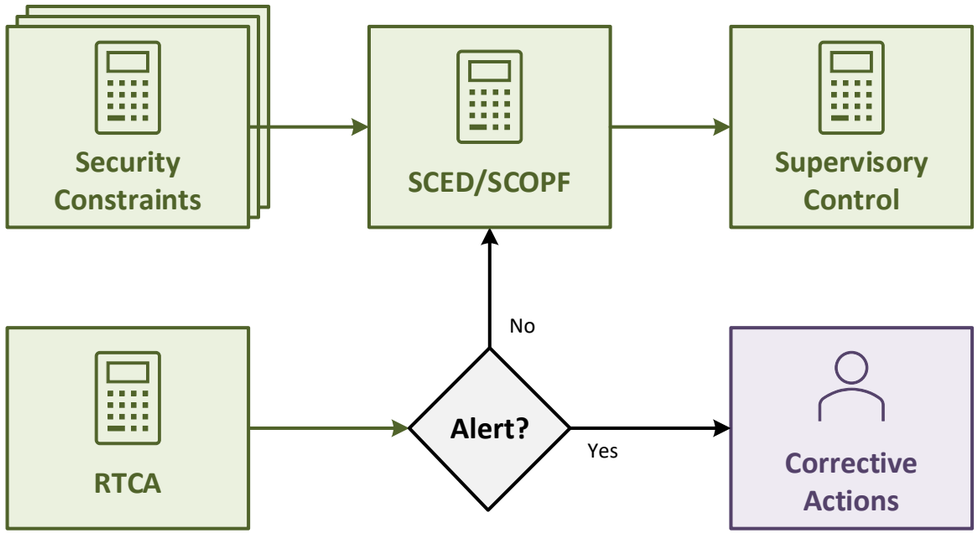
Reduce the cost of providing electricity under all conditions.

Security Recommender

Prepare above-and-beyond contingency security mandates.

Thrust 2: Differential Recommendation





Differential Recommendation

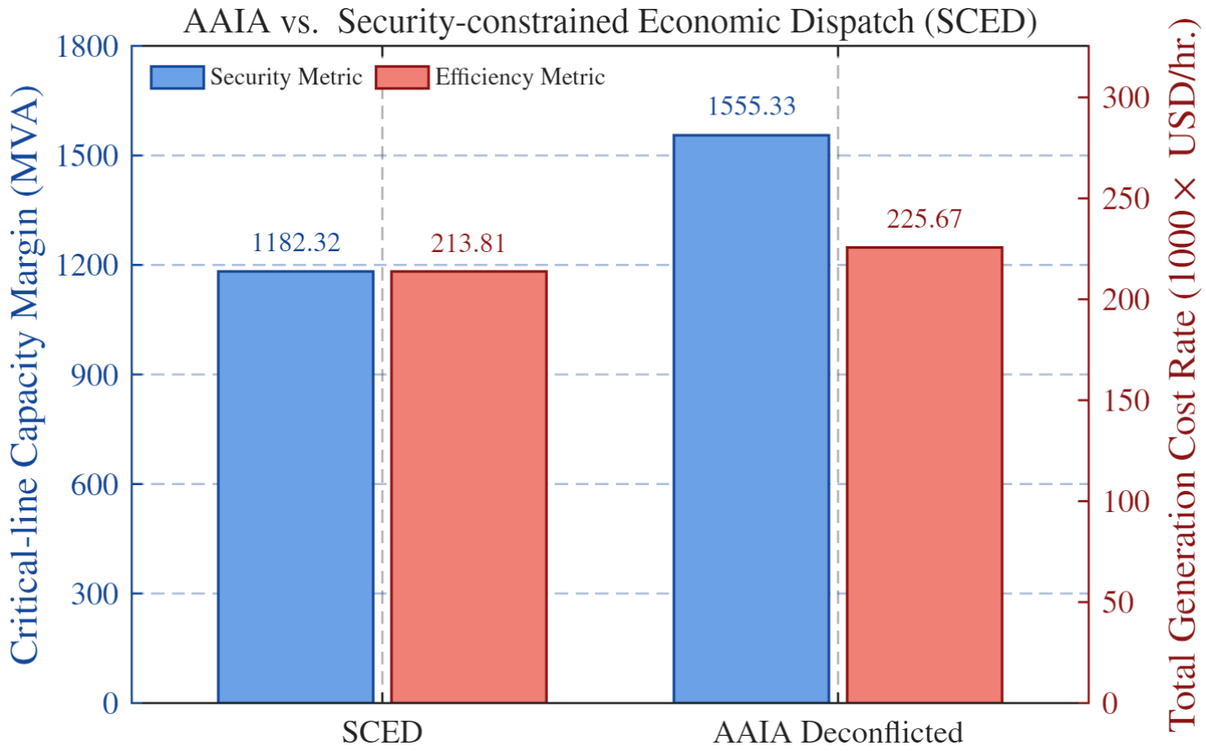
- Helps re-secure grid after events
- Dynamic balancing between objectives
- Respects N-1 security when possible

State-of-the-Art SCOPF

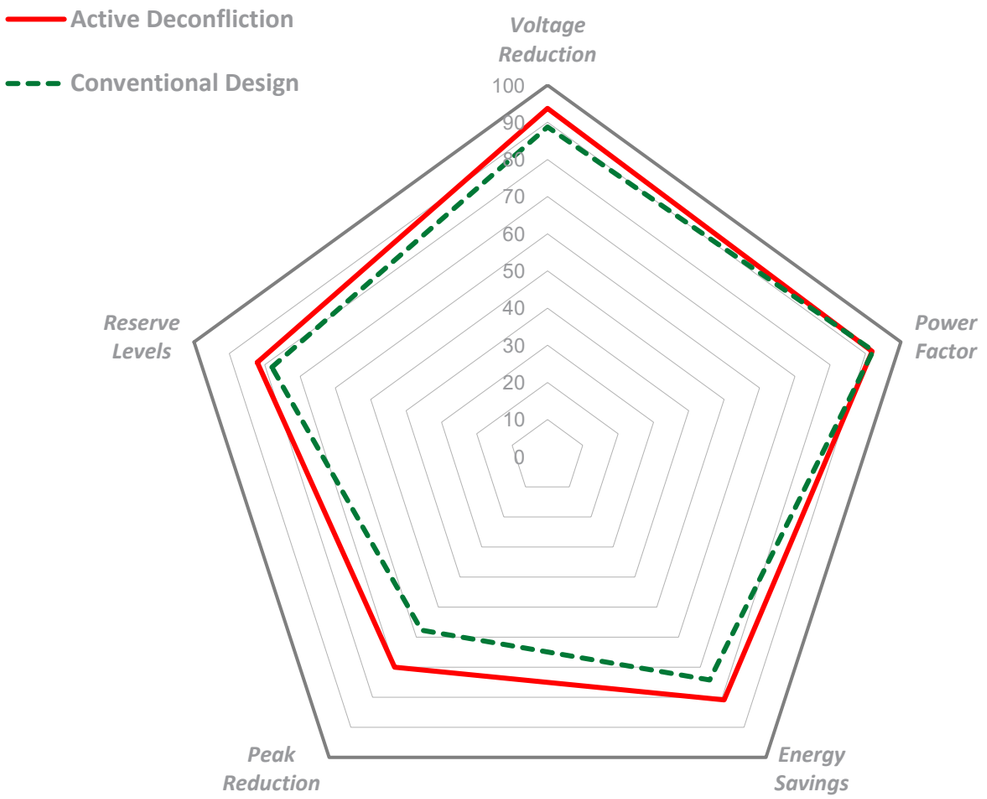
- Disabled during alerts/emergencies
- Rigid prioritization of specified contingencies
- Works only when N-1 security is feasible

Example: AAIA vs. Security-Constrained Economic Dispatch

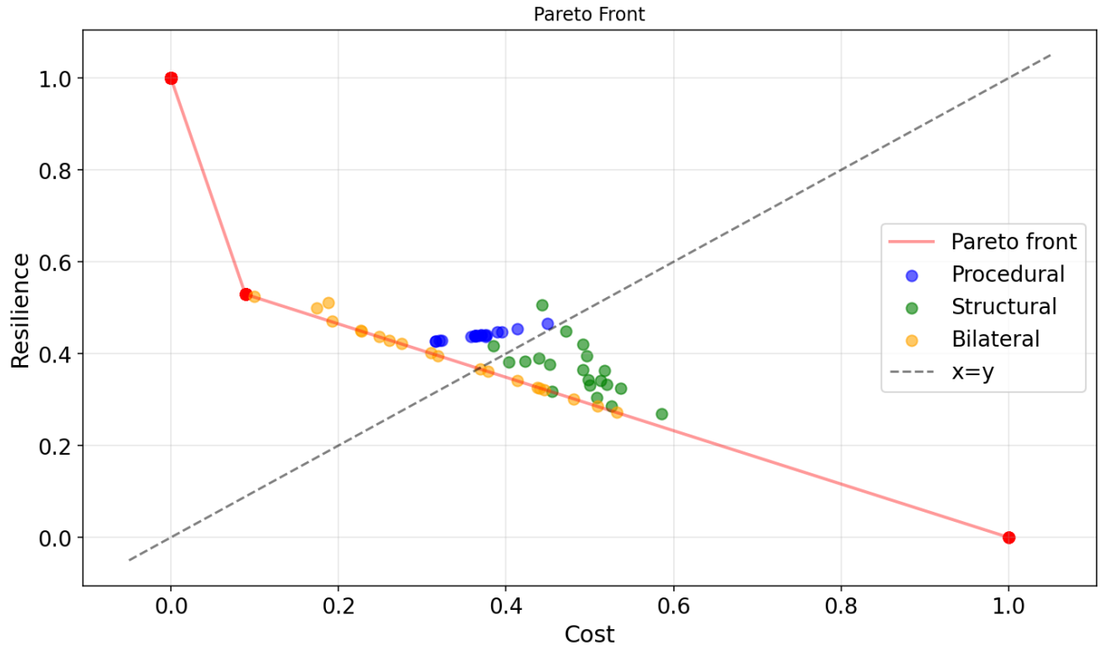
The AAIA solution (compared to SCED) achieves a **large increase (31%) in security** (available capacity in 10 critical lines) at the expense of a **small increase (5%) in cost-of-generation**.



Agent Deconfliction for Win-Win Compromise



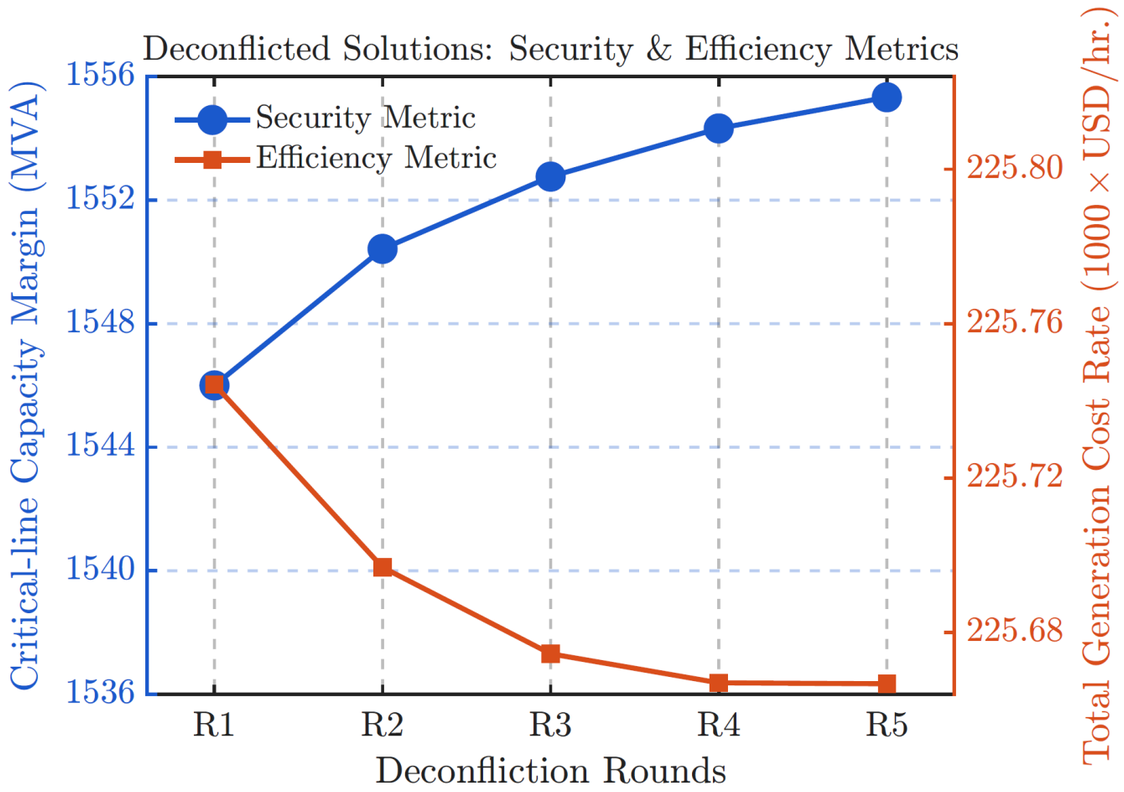
App deconfliction demonstrating win-win compromises.



Deconfliction applied to agentic recommenders.

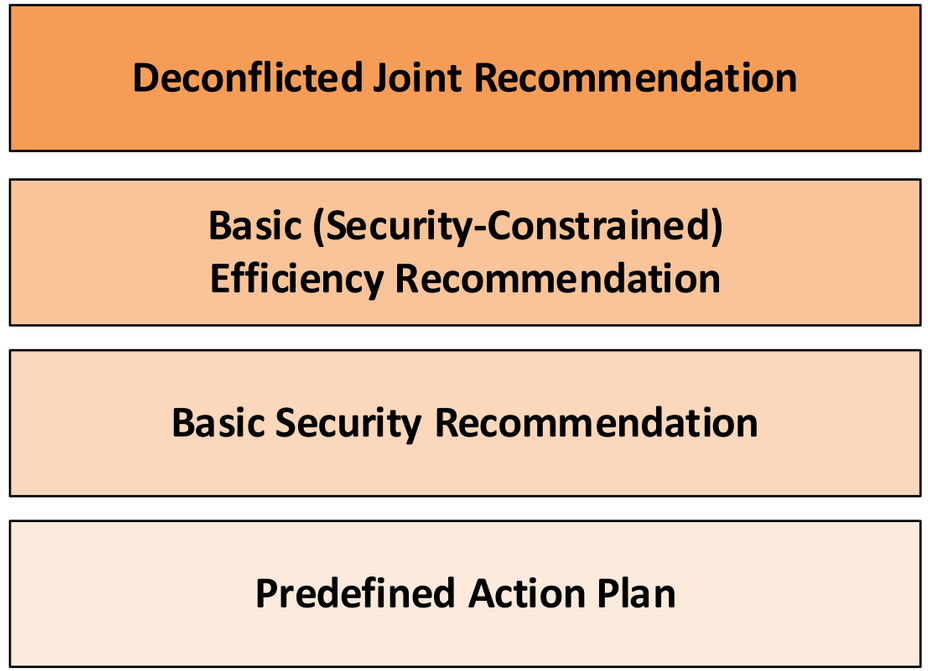
Example: Mediator in Action

R1 through R5 reconciliation proposals from the Mediator. The deconfliction process pursues win-win (win/no-lose) compromises during Pareto-front-seeking iterations.

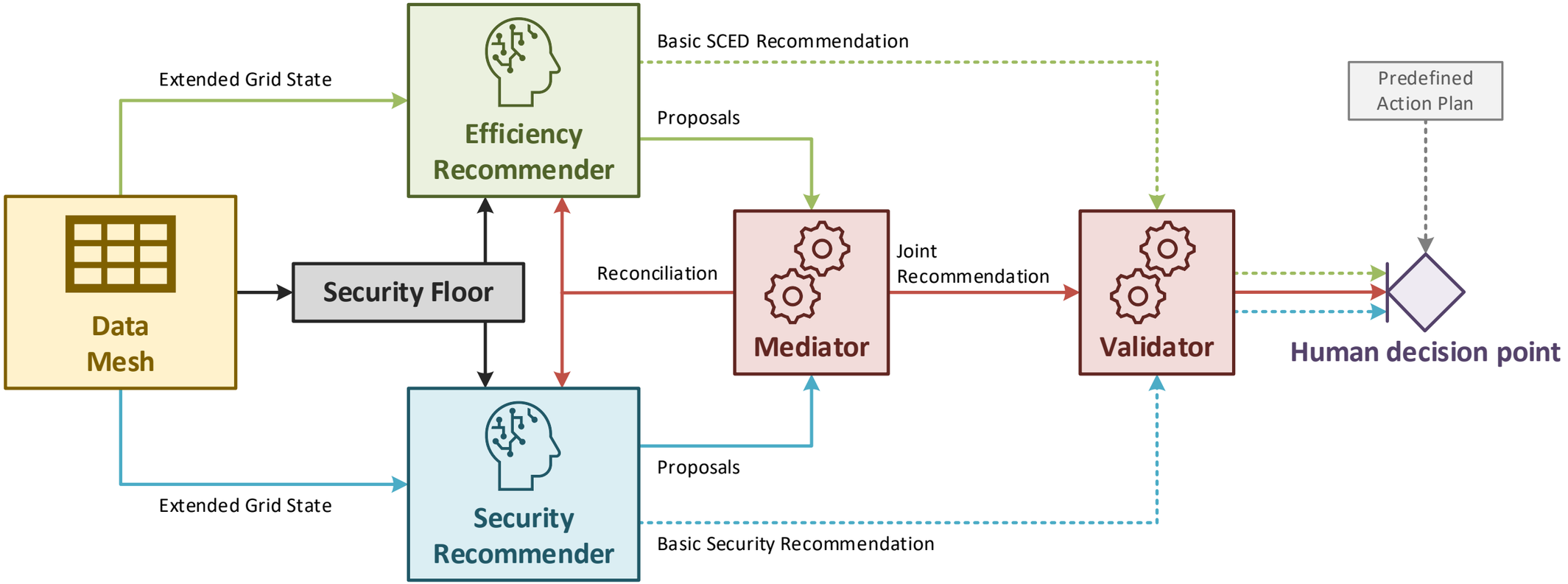


Recommendation Priority List

1. Joint Recommendation.
2. Basic SC-Efficiency Recommendation if time is constrained.
3. Basic Security Recommendation if the Security Floor is infeasible.
4. Predefined Action Plan if immediate action is required.

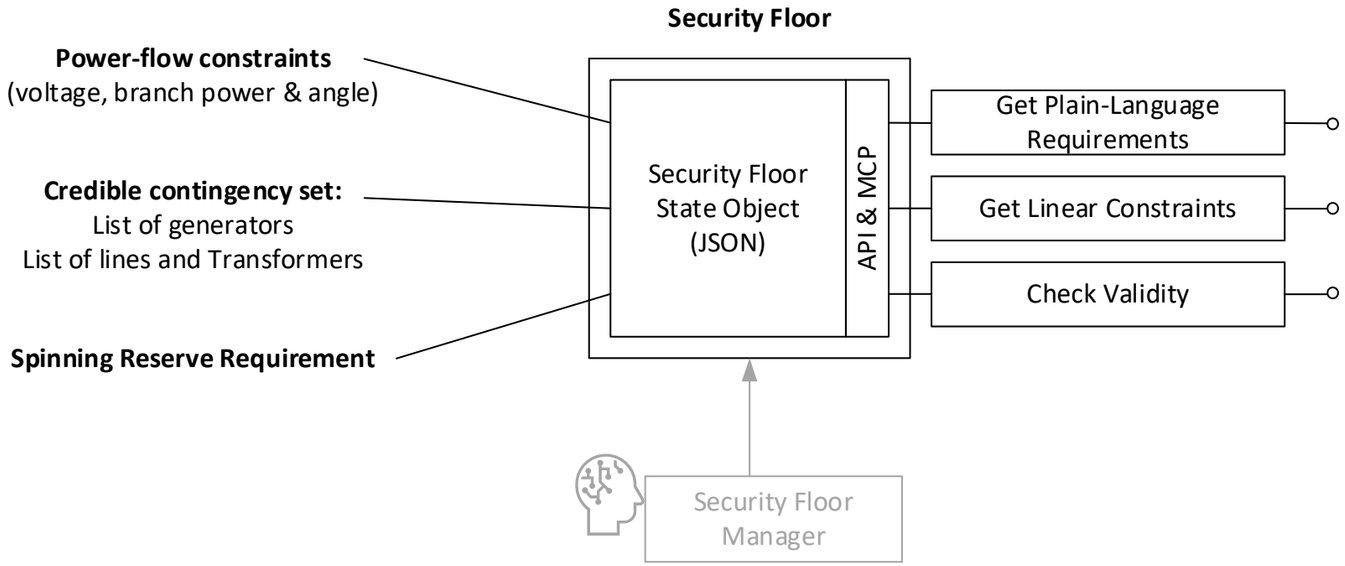


AAIA Agentic Workflow



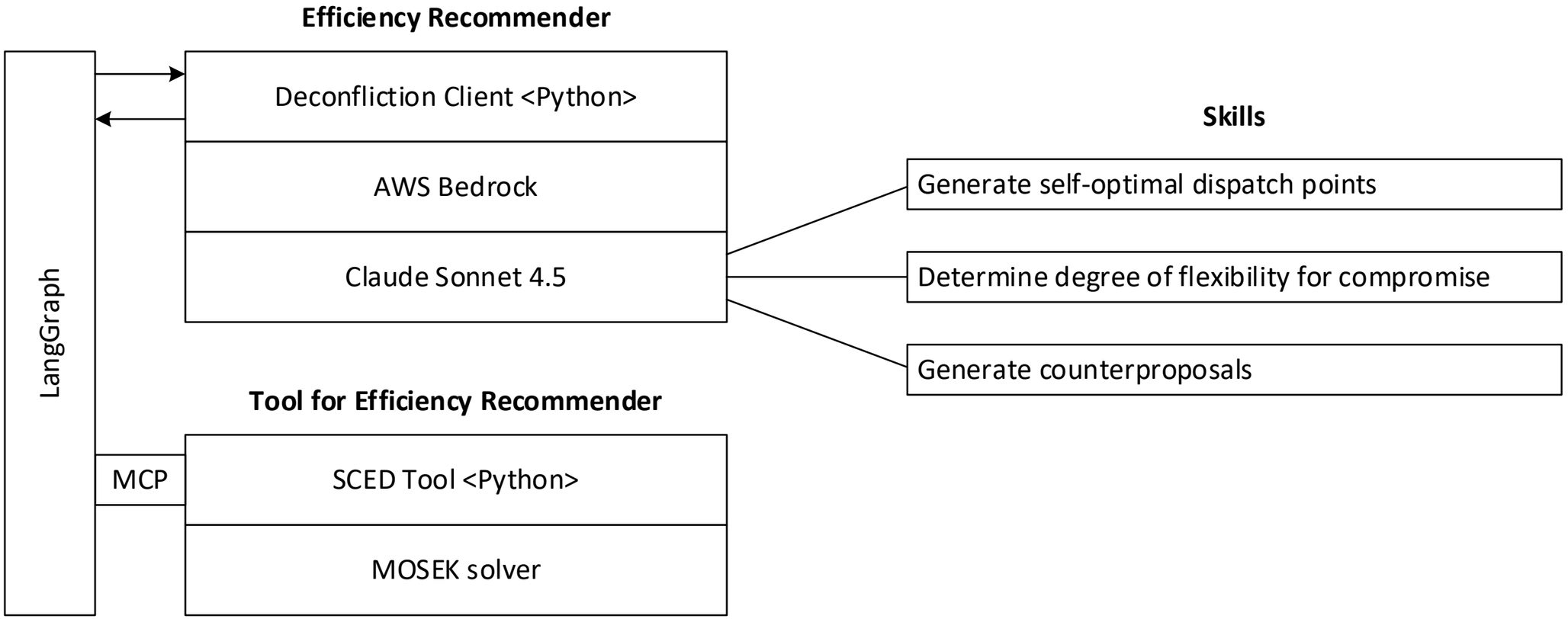
Security Floor – Nonnegotiable Requirements

- Constraints and requirements that are nonnegotiable are described by the Security Floor.
- Agents and the mediator are bound by the security floor.
- Recommendations are validated procedurally before being passed to the operator.
- If the Security Floor is infeasible, no negotiation is performed.

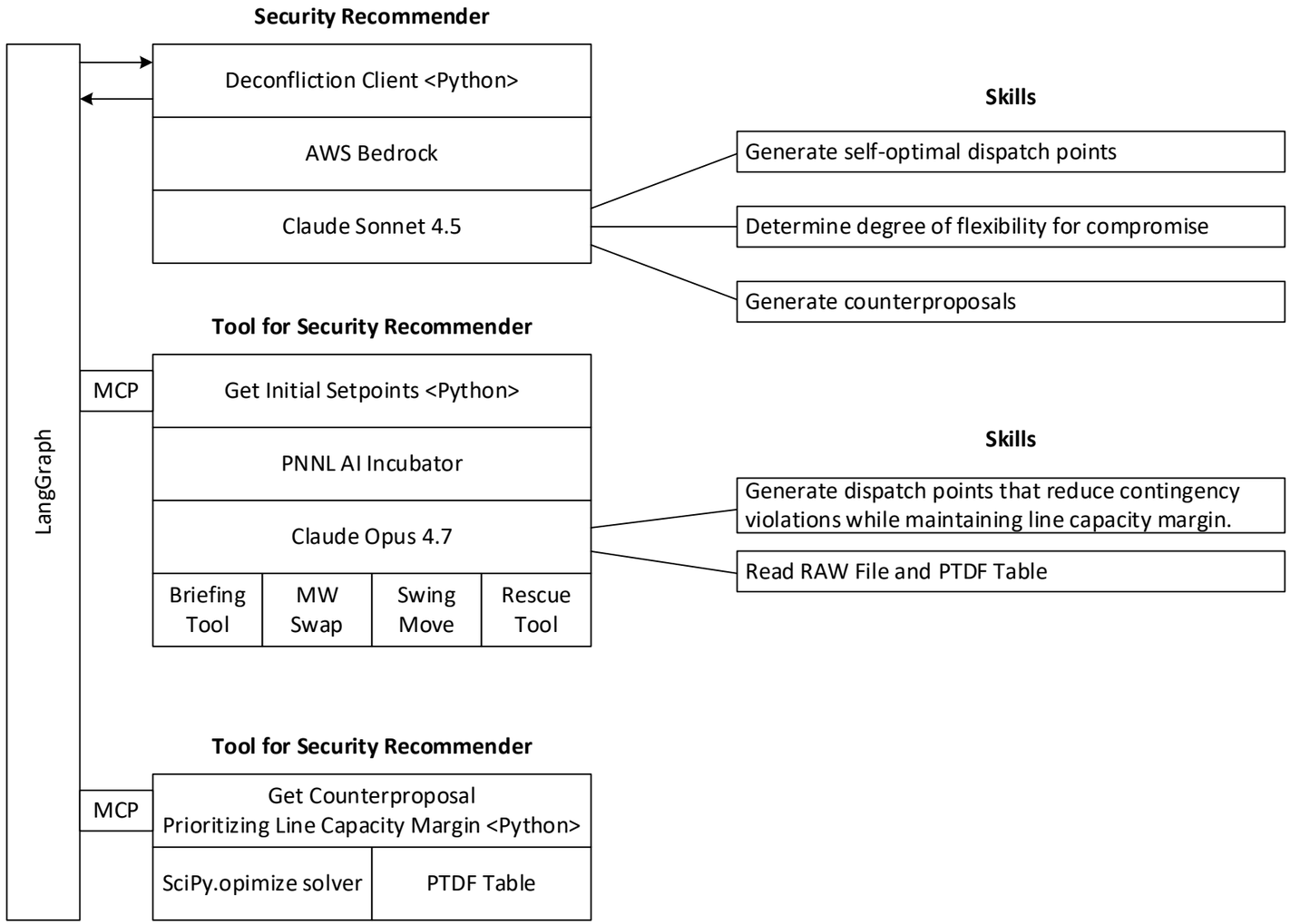


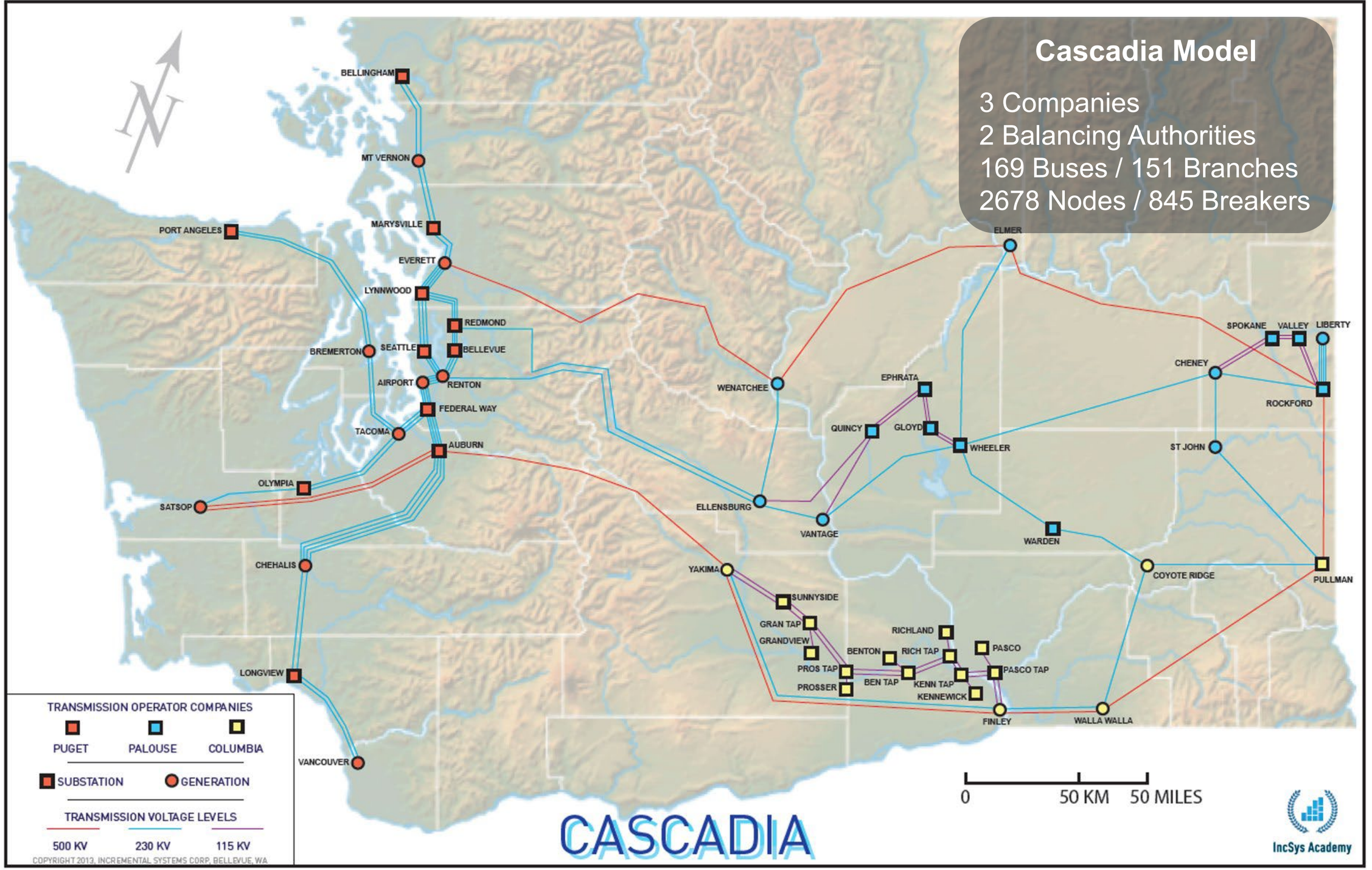
Security floor conceptual design

Anatomy of a Sentinel: Efficiency Recommender



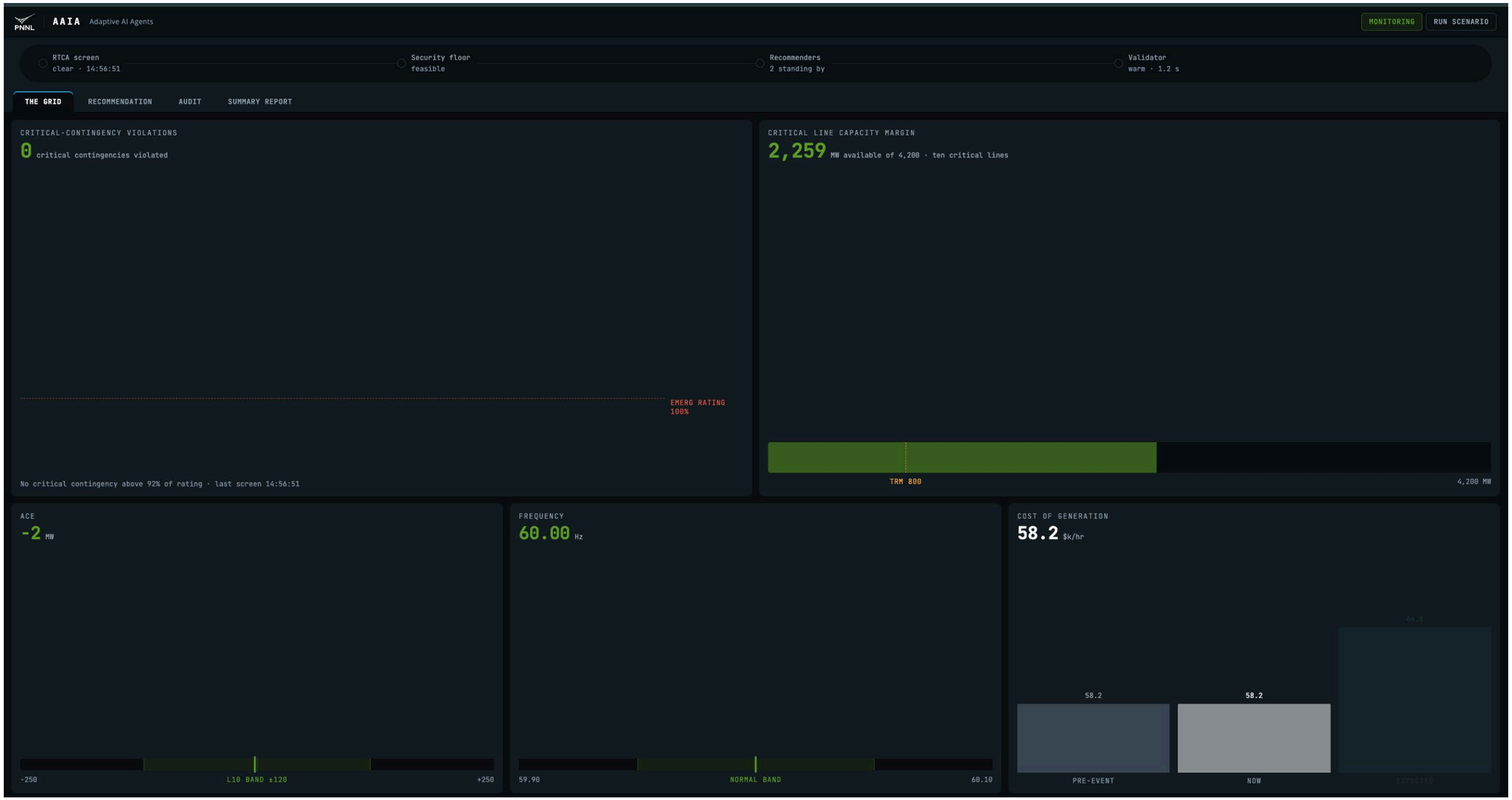
Anatomy of a Sentinel: Security Recommender




Cascadia Model
3 Companies
2 Balancing Authorities
169 Buses / 151 Branches
2678 Nodes / 845 Breakers
BELLINGHAM
MT VERNON
PORT ANGELES
MARYSVILLE
EVERETT
LYNNWOOD
REDMOND
BREMERTON
SEATTLE
BELLEVUE
AIRPORT
RENTON
FEDERAL WAY
TACOMA
AUBURN
OLYMPIA
SATSOP
CHEHALIS
LONGVIEW
VANCOUVER
WENATCHEE
ELMER
EPHRATA
QUINCY
GLOYD
WHEELER
ELLENSBURG
VANTAGE
YAKIMA
SUNNYSIDE
GRAN TAP
GRANDVIEW
PROS TAP
PROSSER
BENTON
BEN TAP
RICHLAND
RICH TAP
KENN TAP
KENNEWICK
PASCO
PASCO TAP
FINLEY
WALLA WALLA
WARDEN
SPOKANE
VALLEY
LIBERTY
CHENEY
ROCKFORD
ST JOHN
COYOTE RIDGE
PULLMAN
TRANSMISSION OPERATOR COMPANIES
PUGET
PALOUSE
COLUMBIA
SUBSTATION
GENERATION
TRANSMISSION VOLTAGE LEVELS
500 KV
230 KV
115 KV
COPYRIGHT 2013, INCREMENTAL SYSTEMS CORP, BELLEVUE, WA
0
50 KM
50 MILES
CASCADIA
IncSys Academy

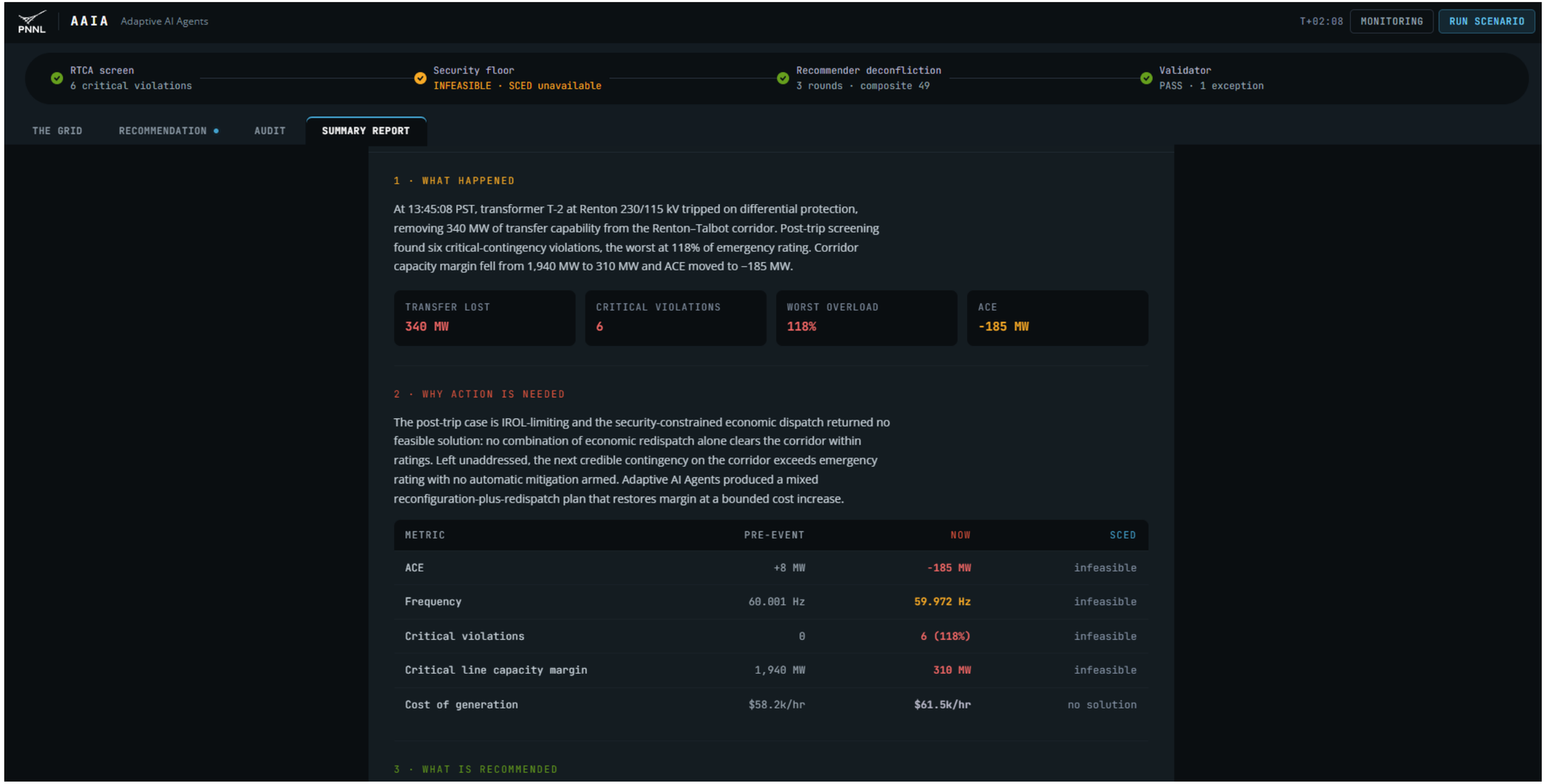
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Prototype: Key Metrics



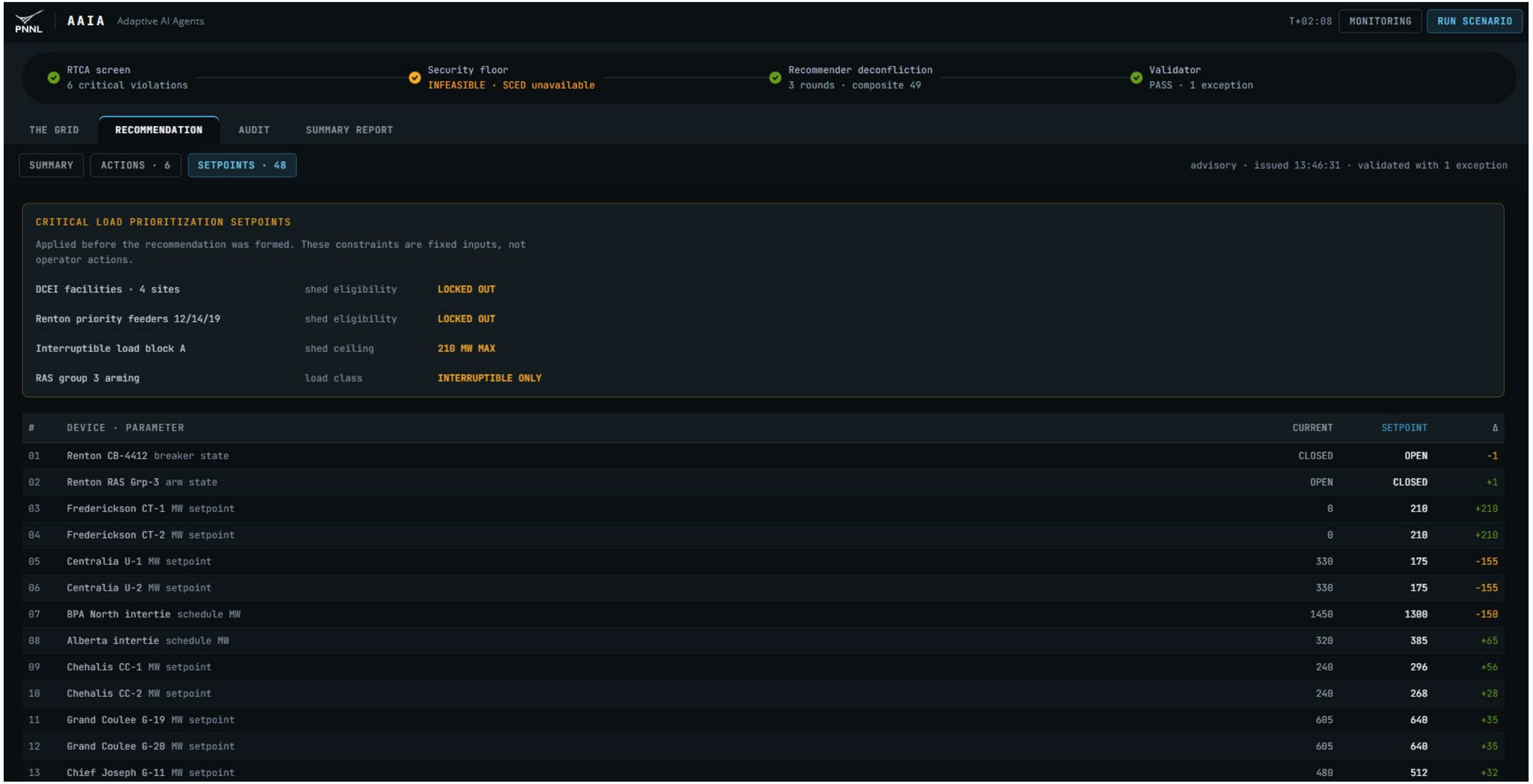
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Prototype: Event and Recommendation Summary



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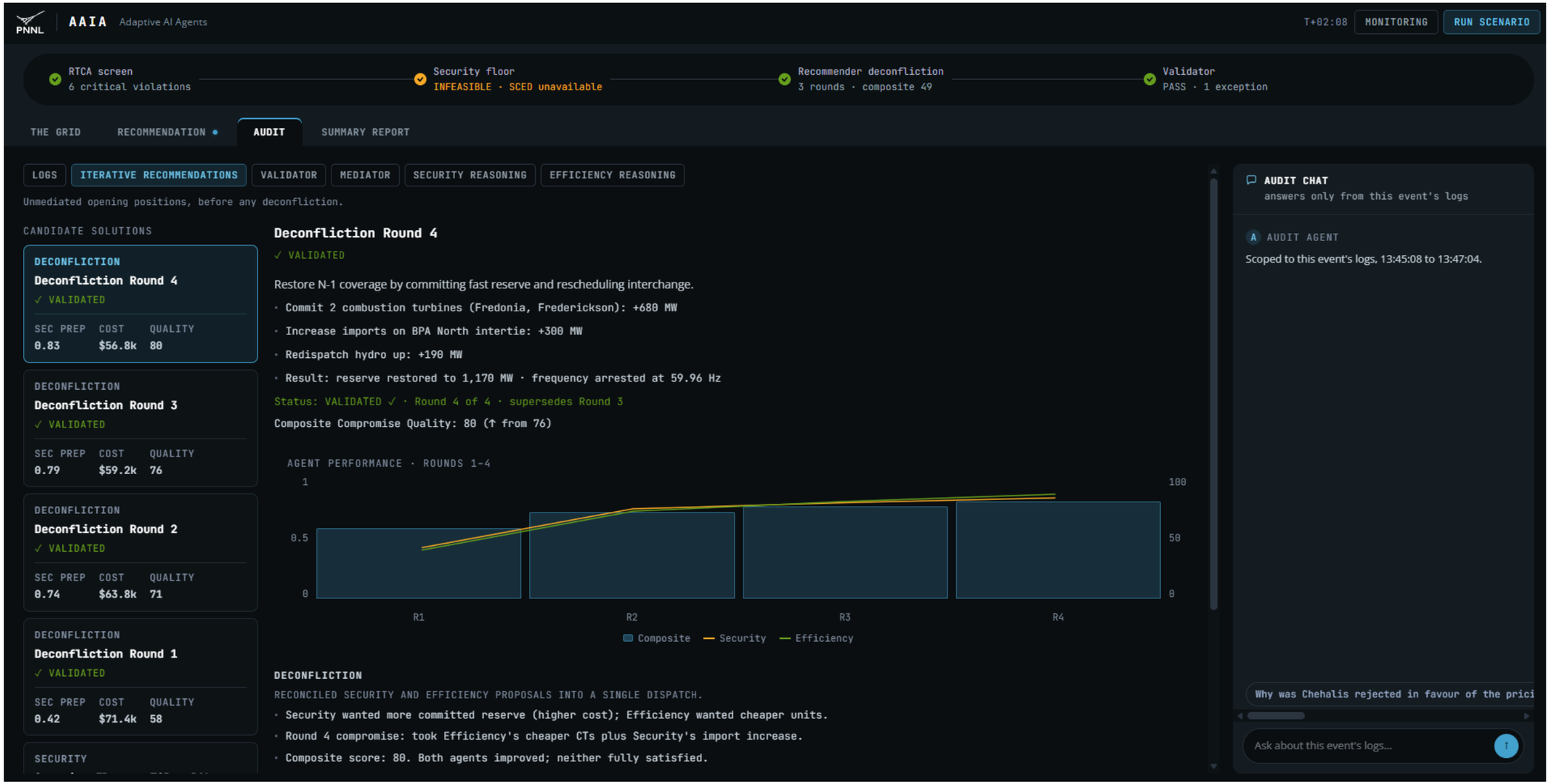
Prototype: Recommendation Review



#	DEVICE · PARAMETER	CURRENT	SETPOINT	Δ
01	Renton CB-4412 breaker state	CLOSED	OPEN	-1
02	Renton RAS Grp-3 arm state	OPEN	CLOSED	+1
03	Frederickson CT-1 MW setpoint	0	210	+210
04	Frederickson CT-2 MW setpoint	0	210	+210
05	Centralia U-1 MW setpoint	330	175	-155
06	Centralia U-2 MW setpoint	330	175	-155
07	BPA North intertie schedule MW	1450	1300	-150
08	Alberta intertie schedule MW	320	385	+65
09	Chehalis CC-1 MW setpoint	240	296	+56
10	Chehalis CC-2 MW setpoint	240	268	+28
11	Grand Coulee G-19 MW setpoint	605	640	+35
12	Grand Coulee G-20 MW setpoint	605	640	+35
13	Chief Joseph G-11 MW setpoint	480	512	+32

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Prototype: Auditing



AAIA Project Team

Todd Hay *(Project Manager)*

Andy Reiman *(Co-PM and Deconfliction Lead)*

Alex Anderson *(Data Mesh Lead)*

Brett Jefferson *(Operator Interface Lead)*

Yousu Chen *(Apps Lead)*

Thiagarajan Ramachandran
Shiva Poudel
Ramij Hossain
Orestis Vasios
Poorva Sharma

Chris Cacciatore
Teresa Chizeck
Kaushik Thallapally
Joely Nelson
Matt Jugovic

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Thank you

