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Piloting a Centralized Remedial Action Scheme (C-RAS) with Emerging Telecomm / Protection Technologies

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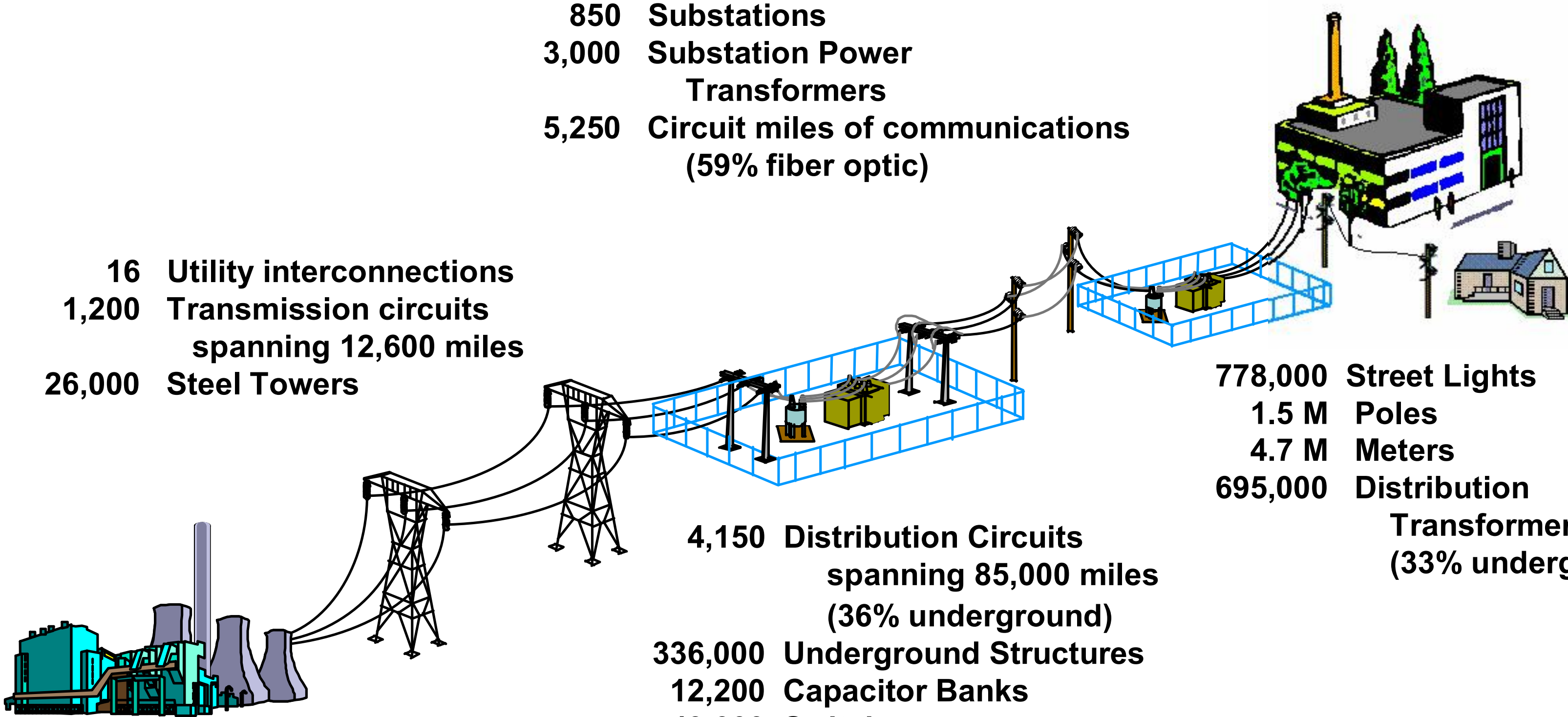
SCE T&D Assets

Generation | **Transmission & Subtransmission** | **Distribution** | **Customer**

- 850 Substations
- 3,000 Substation Power Transformers
- 5,250 Circuit miles of communications (59% fiber optic)

- 16 Utility interconnections
- 1,200 Transmission circuits spanning 12,600 miles
- 26,000 Steel Towers



- 778,000 Street Lights
- 1.5 M Poles
- 4.7 M Meters
- 695,000 Distribution Transformers (33% underground)

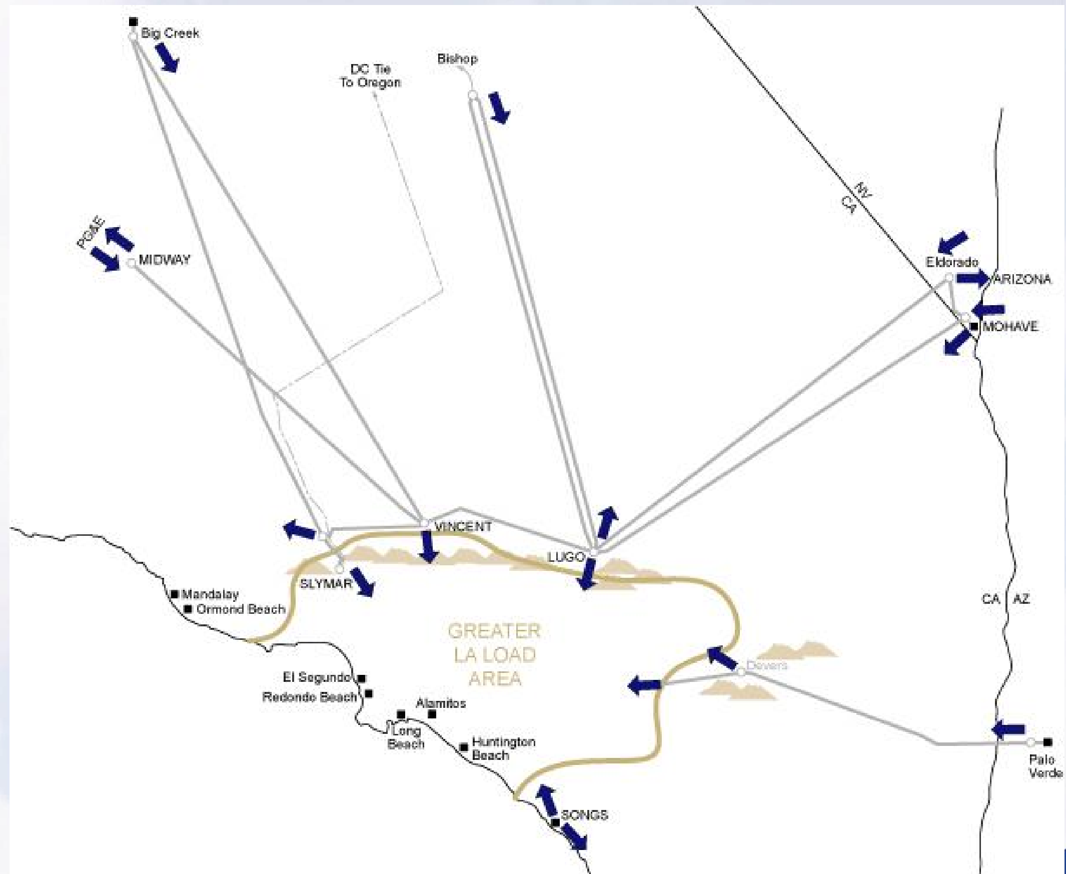
- 4,150 Distribution Circuits spanning 85,000 miles (36% underground)
- 336,000 Underground Structures
- 12,200 Capacitor Banks
- 49,000 Switches
- 39,300 Relays
- 11,500 Circuit Breakers
- 1,017 Automatic Reclosers

Note: Data as of year-end 2005

SCE Transmission Network

Key Transmission Planning/ Operational Issues

- **Congested transmission corridors/ network**
  - Ever increasing customer load growth
- **Long lead time to build transmission**
  - Transmission lagging generation and customer load growth
- **Integration of new generators including renewables into the transmission network**
  - Uncertainty on new generation siting/locations
  - Legislative/regulatory renewable targets mandate
- **Increasing transmission voltage support requirements**
- **Extensive use of "Remedial Action Schemes (RAS)**



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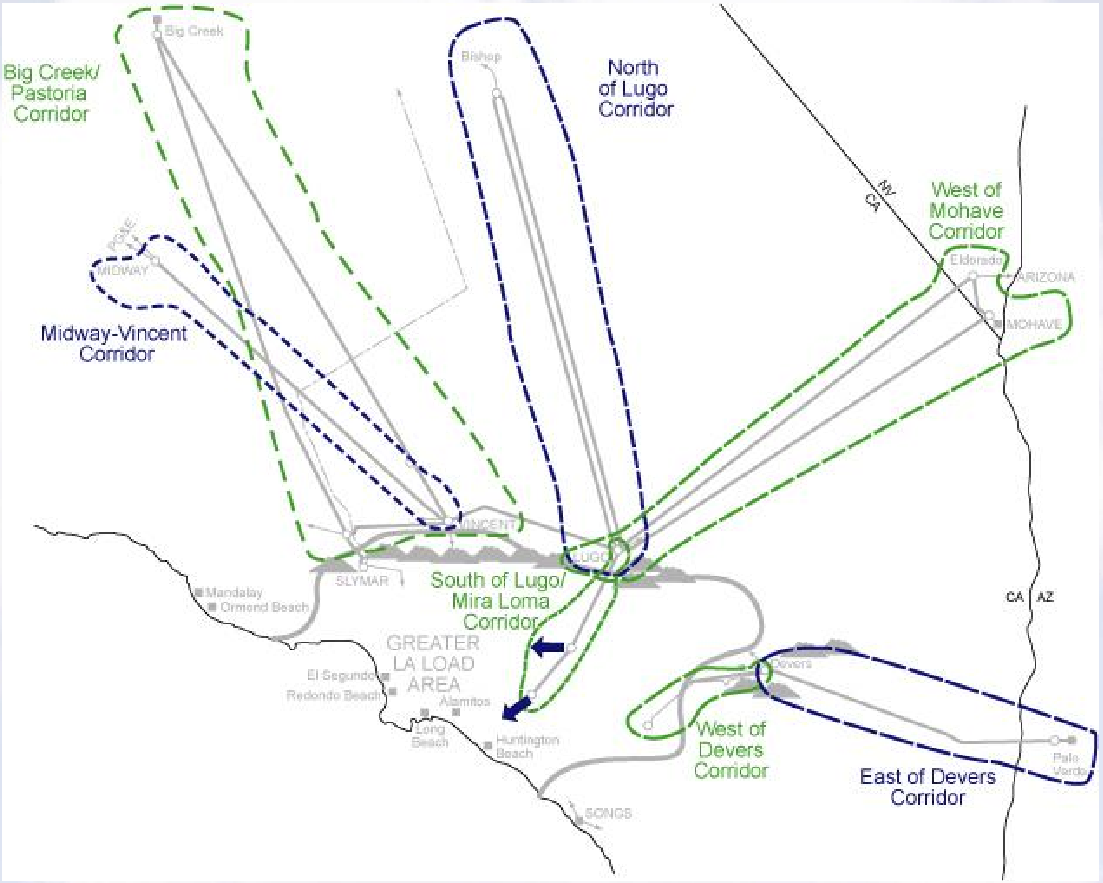
SCE Transmission Corridors and Proliferating RAS Schemes



- **Existing RAS = 17 on all transmission corridors**
- **Expected potential new RAS (2007-2009) = 28**
- **RAS impacted transmission**
  - Generation tripping
  - Load shedding

Voltage	Miles of Transmission Circuits	
	Total Miles	RAS Monitored (%)
500 kV	**1,183**	**1,069 (90% of mi.)**
230 kV	**3,574**	**1,181 (33% of mi.)**
115 kV	**1,846**	**350 (19% of mi.)**
All	**6,603**	**2,600 (40% of mi.)**

Key Observation: Almost all bulk power lines bringing generation / imports into the greater Los Angeles basin load area are being monitored for contingencies and flow levels, and controlled by local RAS schemes.

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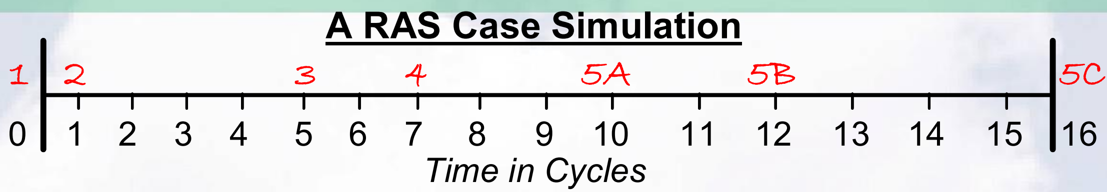
RAS Timeline



1 cycle = 16.7 milliseconds

	Time	Operational Events
Step 1	@ 0 Cycle	3 Phase Fault on the Bus
Step 2	@ 1 Cycle	Relay Processing time for trip signal to CBs
Step 3	@ 5 Cycles	Open CBs for line/transformer out
Step 4	@ 7 Cycles	RAS Logic Processing for trip signal to CBs to trip generators
Step 5A	@ 10 Cycles	Open CBs associated with 12 generators (I Batch Mitigation)
Step 5B	@ 12 Cycles	Open CBs associated with 4 generators (II Batch Mitigation)
Step 5C	@ 16 Cycles	Open CBs associated with 2 generators (III Batch Mitigation)

Event Detection Fault Clearing: 5 Cycles

RAS Processing: 2 Cycles

Mitigation Generation Tripping / Load Shedding: 9 Cycles

Total Elapsed Time: 16 Cycles

Key Findings and Issues with Local RAS Schemes

- LABORIOUS: Planning, design, programming, implementation and operational tasks
- PROLIFERATION: Almost all transmission network involved
- INCREASING DEPENDENCY: 31 new schemes identified in the Generator “Queue” (2007-2009)
- CUSTOMIZATION: No ability to replicate a scheme and high maintenance costs
- ONE SIZE FITS ALL: Inability to size mitigation targets based on dynamic assessment of generation tripping / load shedding requirements
- OVERLAP: Generation / Load subject to interruption for numerous reasons
- SLOW ARMING/DISARMING: Arming by EMS computer may take 8–16 seconds delayed signals
- TIME LOSS: Excessive travel time by engineering and field staff to maintain the local RAS schemes at numerous sites
- NUMEROUS REVISIONS: Expanding Generator “Queue” and network changes affects existing local RAS schemes
- LOW STAFF MORALE: The impossible problem of increasing work load, short deadlines, proliferating archaic technology and losing skilled staff (added 2 new & updated 3 RAS schemes for 2006 summer)

SOLUTION

A Centralized RAS (C-RAS) Plan

Key Requirements for C-RAS Scheme Speed Testing

A. Protection/Computing/Data Packets Over Ethernet Protocol

1. Line Flows for Arming → PMU
2. Line Outage Detection → Relay
3. Logic Processing with GOOSE Data Packets → Computer
4. Mitigation Action Signal → Relay

Solution →

GE N-60
Universal Relay

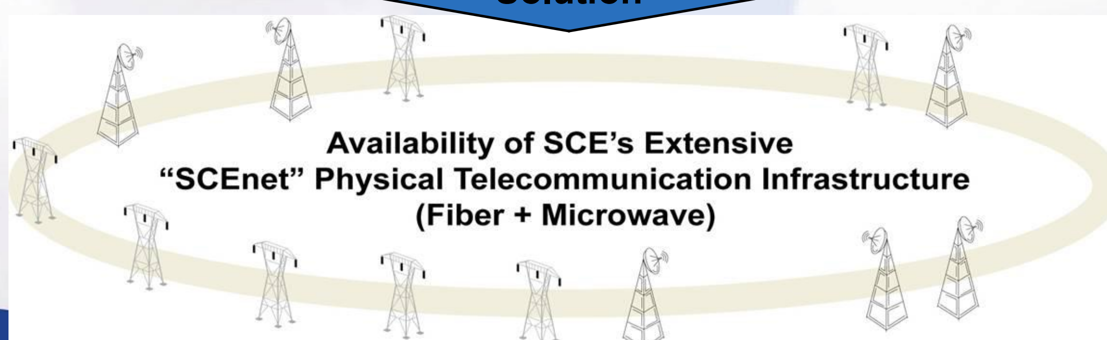
Capabilities:

- **Synchrophasor PMU**
- **Outage/Mitigation relay functions**
- **CPU processor with GOOSE data packets**

B. Telecommunication Infrastructure

1. Availability of Telecomm. Circuits to substations on each corridor → Two T1 circuits for each corridor
2. Adequate Bandwidth and Speed for GOOSE Data Packets → T1 = 1.544 Mbps
3. Network distances to be covered → 100 – 660 miles
4. Desired Speed for C-RAS → < 50 ms

Solution



Layout of the C–RAS Scheme Concept With Emerging Telecomm/Protection Technologies

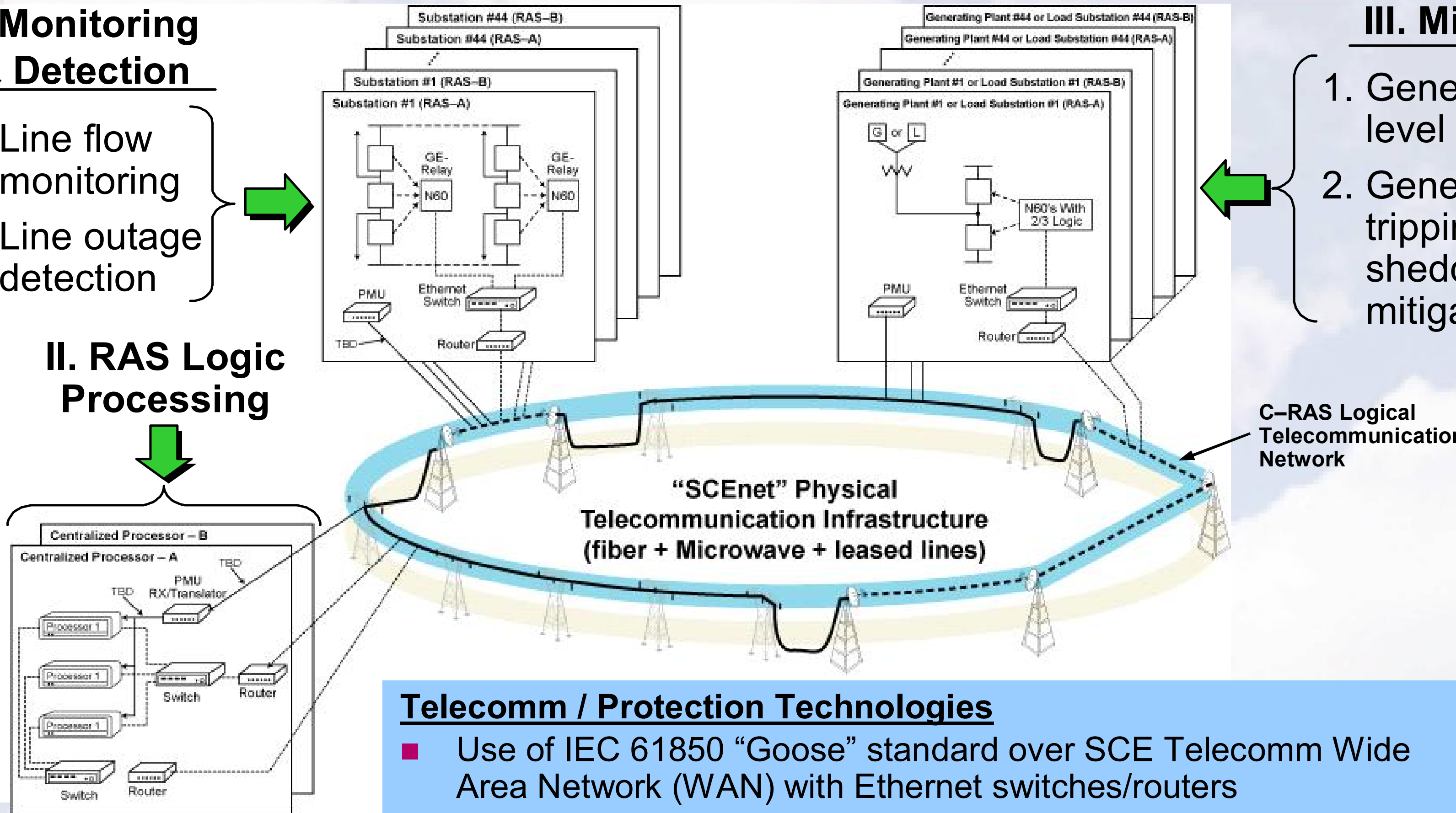
I. Monitoring & Detection

1. Line flow monitoring
2. Line outage detection

II. RAS Logic Processing

III. Mitigation

1. Generation/ load level monitoring
2. Generation tripping/load shedding mitigation



Telecomm / Protection Technologies

- Use of IEC 61850 "Goose" standard over SCE Telecomm Wide Area Network (WAN) with Ethernet switches/routers
- Use of N-60 relays (GE or other) for line outage detection & mitigation signal delivery
- Use of triple redundant Programmable Logic Controller (PLC) – Computing Processors

What is in a GOOSE?
(Generic Object Oriented Substation Event)

An IEEE approved data packet standard – IEC61850 over Ethernet protocol

- LAN Priority

```
⊞ 802.1Q Virtual LAN
⊟ IEC 61850 GOOSE
    AppID: 0x0000
    PDU Length: 769
    Reserved1: 0x0000
    Reserved2: 0x0000
  ⊟ PDU
      [APPLICATION 1]  (length = 757)
     GOOSE Control Reference (length=13): mydom/mygcRef
     TimeAllowedToLive (length=1): 4 msec
     DataSet Reference (length=15): mydom/mydataset
     Application ID(length=9): testAppID
     Event Timestamp: 2004-01-06 22:10.20.000000  Timequality: 00
     State Change Number (length=1): 1
     Sequence Number (length=1): 1
     Test Mode (length=1): FALSE
     Config Rev Number (length=1): 32
     Needs Commissioning (length=1): FALSE
   ⊞ Num Data Entries (length=1): 3
```

GOOSE Data: Complexity is Allowed

Metered Data – Flow amps, voltages, phase angles, weather, etc.

```
⊟ DATA[002]
    {
      UNSIGNED: 3
      FLOAT: 4.234000
      UNSIGNED: 5
      FLOAT: 6.234000
      UNSIGNED: 7
      FLOAT: 8.235000
      UNSIGNED: 9
      FLOAT: 10.235000
      BITSTRING:0101010101010101
      BTIME06: 2000-07-04 23:59:14.432 (days=6022 msec= 691154432)
    }
```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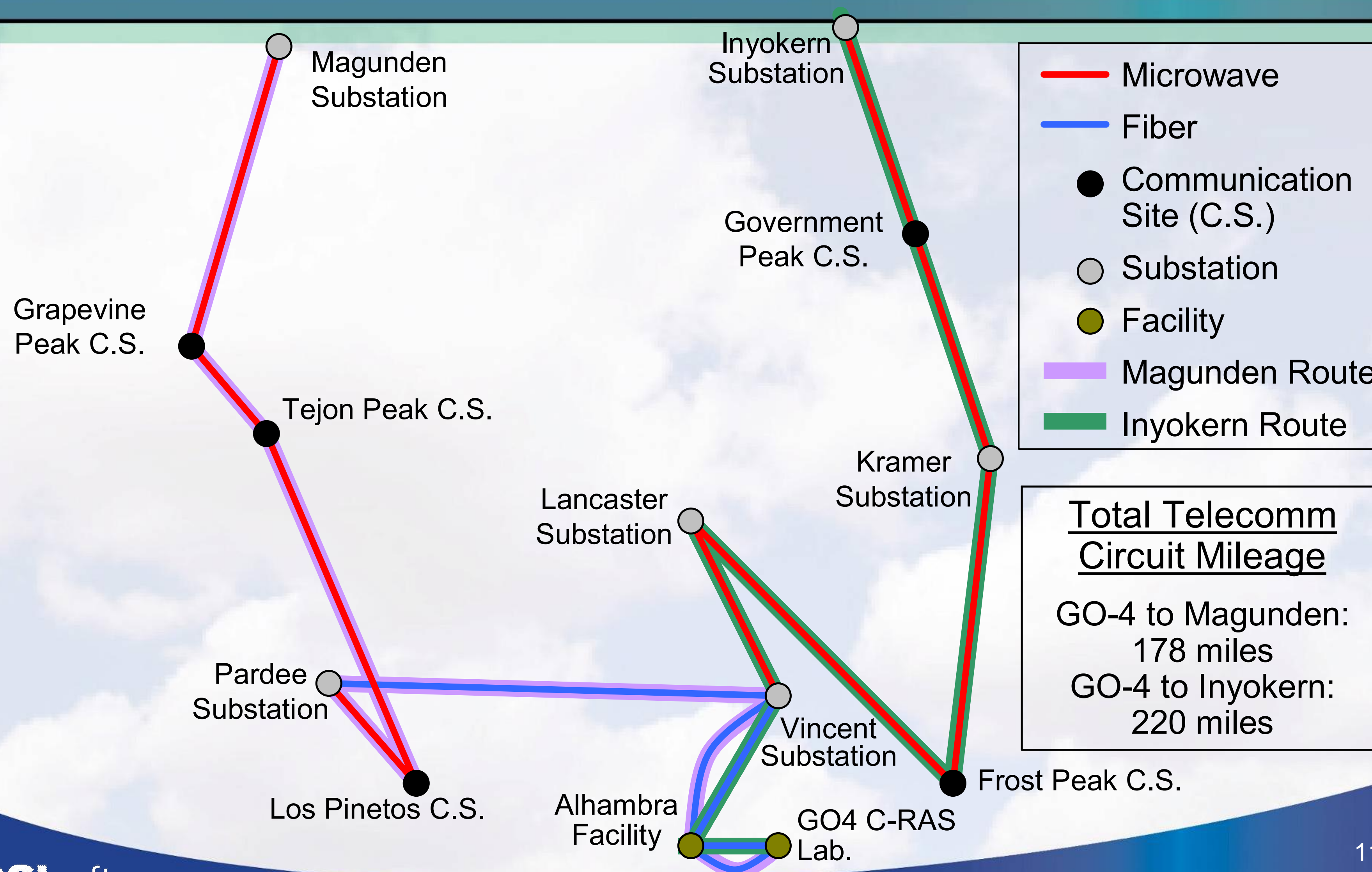
Magunden and Inyokern Telecommunication Circuit Routes



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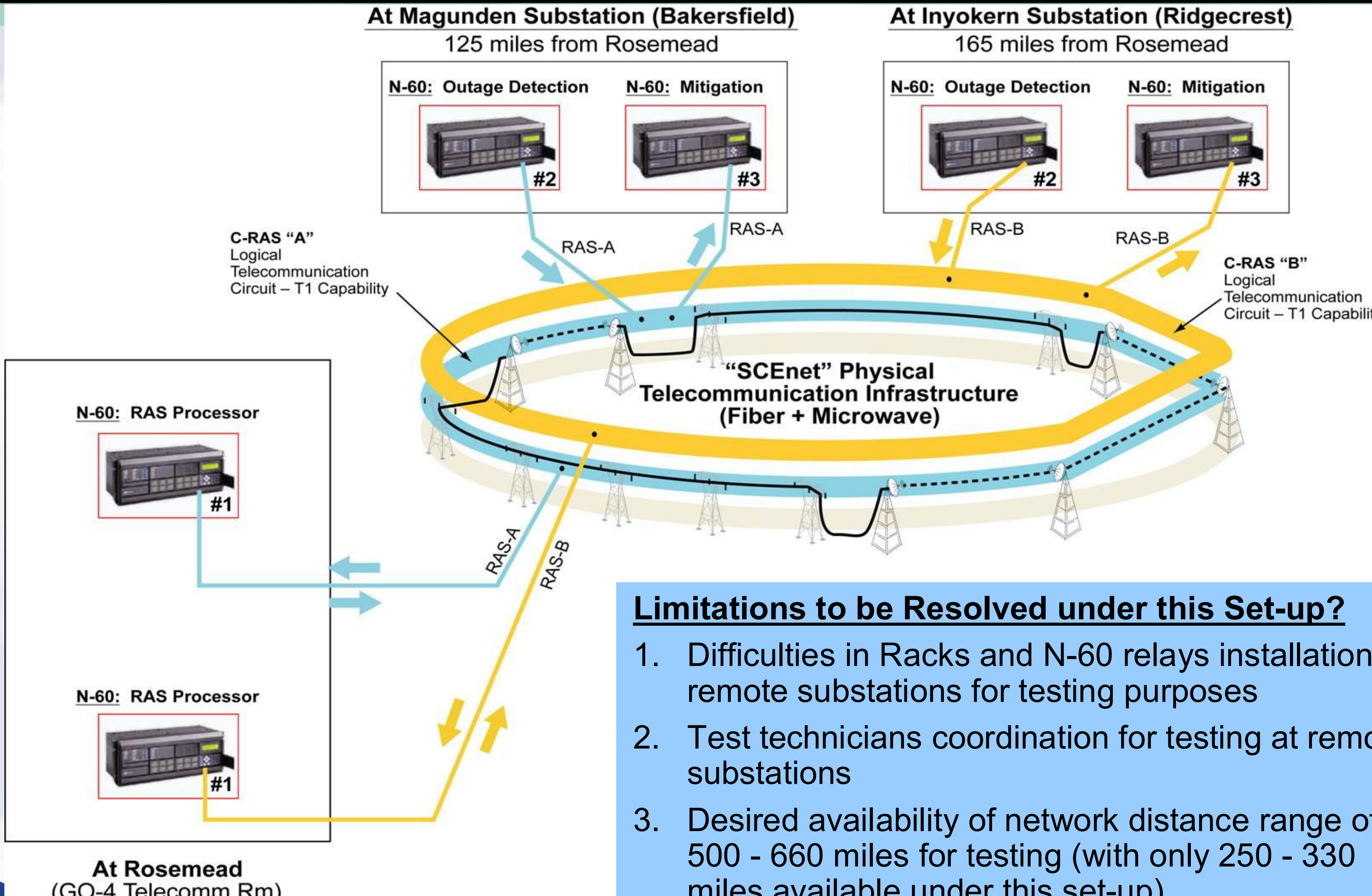
Proposed Telecomm / Protection Relay Set-Up for initial C-RAS Scheme Testing



Limitations to be Resolved under this Set-up?

1. Difficulties in Racks and N-60 relays installation at remote substations for testing purposes
2. Test technicians coordination for testing at remote substations
3. Desired availability of network distance range of 500 - 660 miles for testing (with only 250 - 330 miles available under this set-up)

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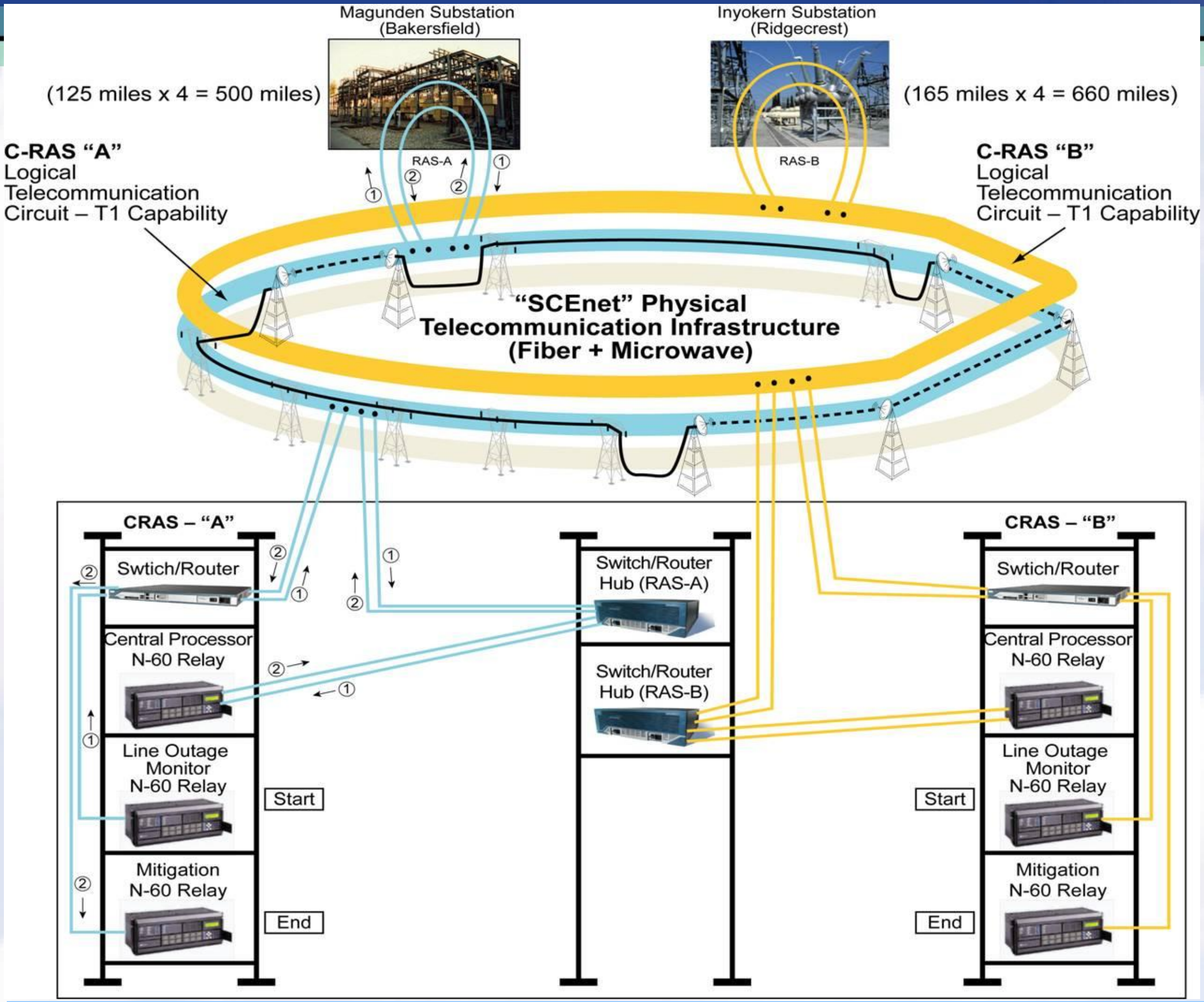
Resolution of Issues for initial C-RAS Scheme Set-Up (Phase – 1)



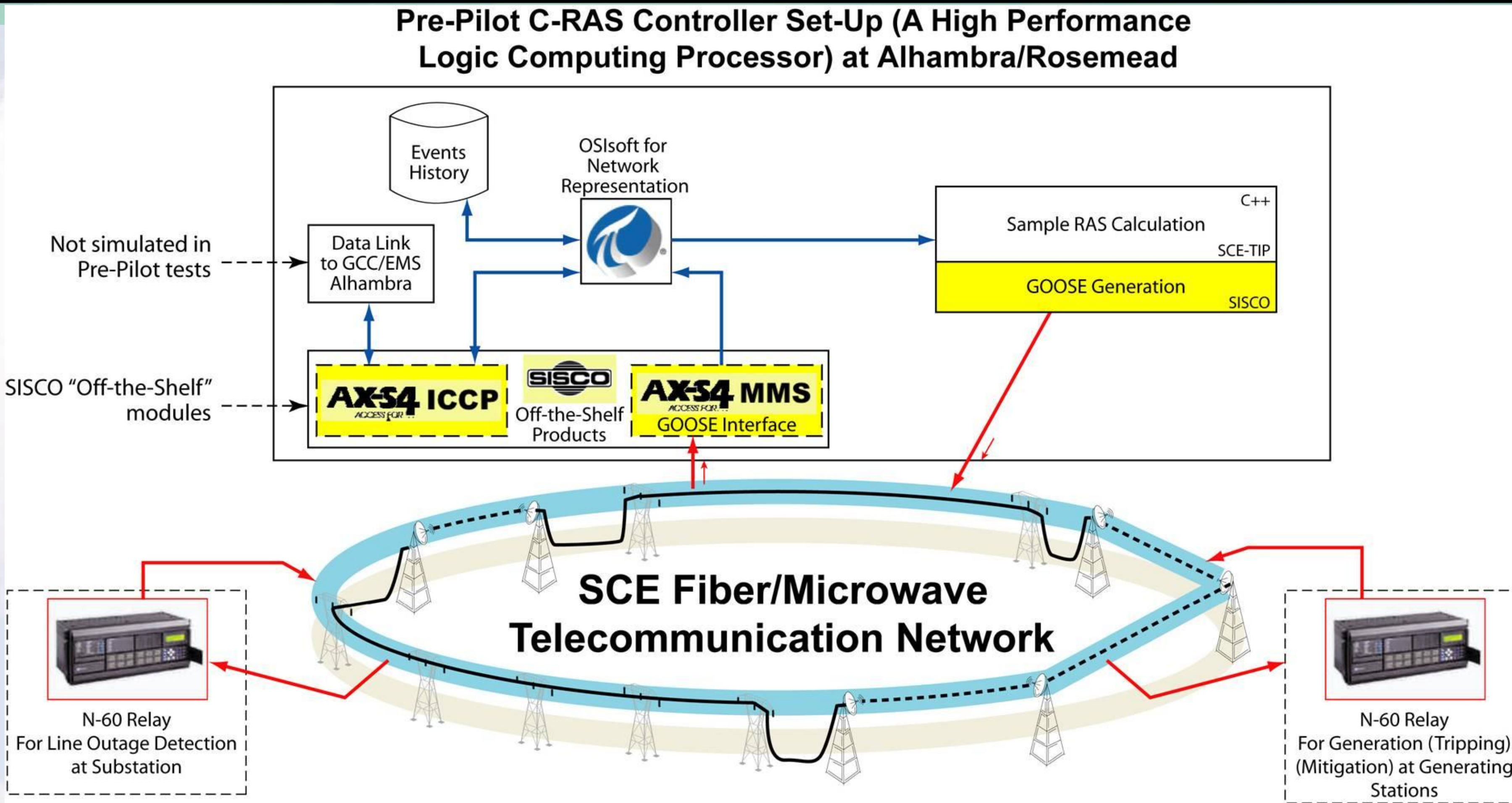
N-60 Relay based Central Processors to be replaced with high Performance Computing Processors as C–RAS logic processors loaded with "Off-The-Shelf" SISCO modules and tools in Phase–2

GO-4 C-RAS Laboratory

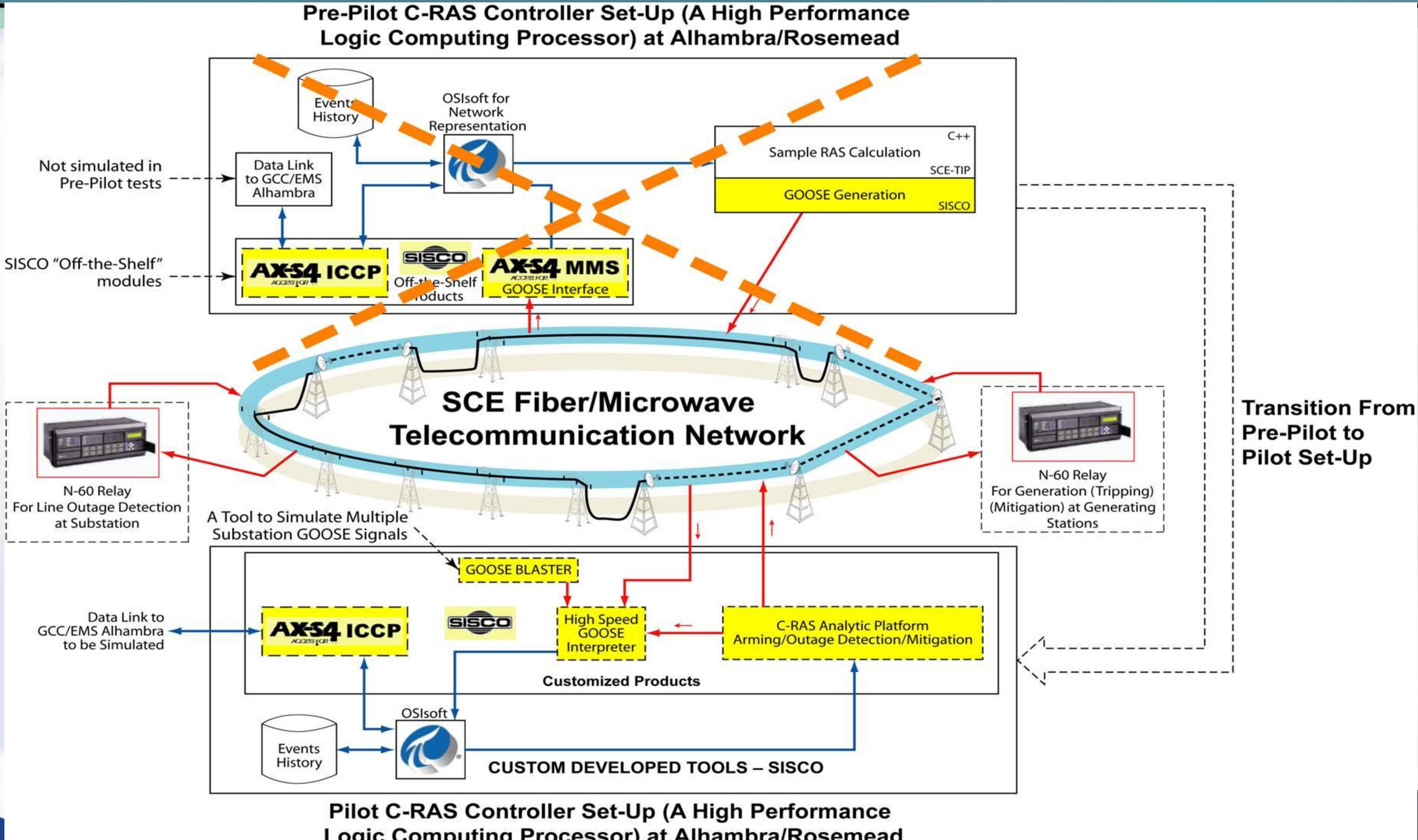
Key Results:

- LAN Speed (local fiber within GO-4 C-RAS Lab.) = 11 - 12 ms
- WAN Speed (500 - 660 miles over SCEnet from Outage detection to Mitigation action delivery) = 20 - 22.5 ms
- Use of IEC 61850 GOOSE standard protocol using N-60 relay GOOSE capabilities

Set-Up With Off-the-Shelf SISCO Tools for C-RAS Pre-Pilot (Phase-2)



Transition From Pre-Pilot (Phase 2) to Pilot (Phase 3) Set-up



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Detailed Scope of the C-RAS Pilot Project

The C-RAS Pilot project will comprise of the following SISCO products and services jointly with SCE:

a. **Engineering, design, development, and installation of the following software & Controller components and provision of module license for the C-RAS Pilot project:**

   i. High Speed GOOSE Logic Interpreter
   ii. GOOSE Blaster
   iii. C-RAS Analytic platform
   iv. C-RAS Arming / Mitigation Logic Algorithms
   v. Controller hardware boxes (Industrial strength computing processors)
   vi. MMS – EASE Lite License

b. **Installation, simulation, experimentation, and testing of the following key C-RAS pilot functionalities:**

   i. High speed interface testing of configurable GOOSE data packets to achieve acceptable performance results (<50 - 60 ms) for line outage detection, logic processing, arming, and mitigation signal delivery
   ii. C-RAS / EMS Data Exchange simulation utilizing CAISO sample network representation in coordination with EMS Power Systems Control group
   iii. Mirror imaging and testing of one existing RAS scheme (South of Lugo RAS)Experimenting with varying RAS calculations and arming algorithms
   iv. C-RAS Scheme Acceptance Test (SAT)
   v. Defining and establishing demarcation points (per Chairman, WECC RAS Task Force) in the C-RAS pilot scheme set-up for diagnostics of signal errors, its resolution, and also presenting the scheme and performance results to WECC RAS Task for their review and approval per NERC / WECC RAS standards

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Review of C-RAS Pilot Testing Results & Current Plan

- Phase 1 Results: Telecommunication speed measurement for generic GOOSE data packets generated from N-60 Relays to cover a distance of 500 – 600 miles over SCEnet Fiber / Microwave infrastructure
  - Speed tested successfully with 21 milliseconds (< 1.3 cycles) time achieved for the following functions:
    - Line outage detection generated by N-60 relays at Magunden & Inyokern substations
    - Generic GOOSE data packet receipt by Controller (N-60 relay) and initiating RAS mitigation step
    - Sending mitigation signal for tripping generators at Magunden & Inyokern substations
- Phase 2 (Pre-Pilot) Results: C-RAS set-up with Off-the-shelf OSIsoft PI & SISCO products with an Industrial C-RAS controller replacing N-60 Relay used in Phase 1 above
  - Speed tested successfully with 40 milliseconds (<2.5 cycles) time achieved for the following functions:
    - Line outage detection generated by N-60 relays at Magunden & Inyokern substations
    - GOOSE data packet receipt, processing, and creation of GOOSE mitigation signal utilizing SISCO & OSIsoft Off-the-shelf products installed on the Controller
    - Sending mitigation signal for tripping generators at Magunden & Inyokern substations
- Phase 3 (Pilot) Plan: C-RAS set-up & testing with comprehensively developed custom products by SISCO consultants & RAS calculation module by TDBU TIP staff to measure performance
  - Capabilities to be tested: Installing C-RAS pilot system with high speed GOOSE data from multiple RAS signals, mirroring of an existing RAS scheme, operating C-RAS pilot in parallel with an existing RAS scheme, Scheme Acceptance test, Documentation, and obtaining approval of the C-RAS technologies and set-up by WECC RAS task force
  - Completion Target: – Planned completion by January 31, 2008

Potential Grid Applications and Benefits From C-RAS Implementation

- Electric System Planning / Network Engineering:
  - Enhanced transmission capacity ratings (up to 5-10%) with shrinking timeline for RAS calculations and capability to fine tune mitigation in place of fixed amounts of mitigation
  - Easier to design, deploy and maintain RAS schemes under varying seasonal and system conditions
  - Capability to deploy C-RAS based solutions to monitor and reduce the risk of system-wide voltage degradation or collapse risks / problems (AC stalling at Valley, Antelope, Rector, Villa Park and Devers substations)
  - Additional study tool for use in Transmission & Interconnection planning
- Grid Operations
  - Grid Control Center
    - Continued capability to arm / disarm a specific RAS operation via C-RAS link
    - Capability to get synchronized time – stamped power system data via C-RAS in place of 4-8 seconds of EMS Scan gaps
    - Potential of dynamic switching to change transmission line loadings
  - Substations
    - Simplified operation methods with better information
    - Improved Operator training methods

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Potential Grid Applications and Benefits From C-RAS Implementation - continued

- Adoption of new Technologies and improved usage of Telecom infrastructure to reduce customer costs
  - Replacement of point – to – point wiring or channels and usage of Wide Area Network (WAN) Ethernet protocol
  - Capability to deploy redundancy in RAS schemes and to achieve improved automation in the testing of RAS schemes
  - Capability to accomplish “Bird’s eye view” of SCE grid by monitoring real-time synchronized time stamped load, generation, imports and rates of change in these power system metrics for improving operations, productivity and processes
  - Capability to implement a pioneering “Real-time Grid Monitoring System” for SCE grid following DOE / FERC approach to achieve a “Smart Grid” operation
- A tool to maintain grid reliability and safety
  - Protects SCE’s growing Transmission / Distribution investments of over $9.5 billion (2006-’10) by reducing the risks of cascading outages leading to major brownouts and / or blackouts

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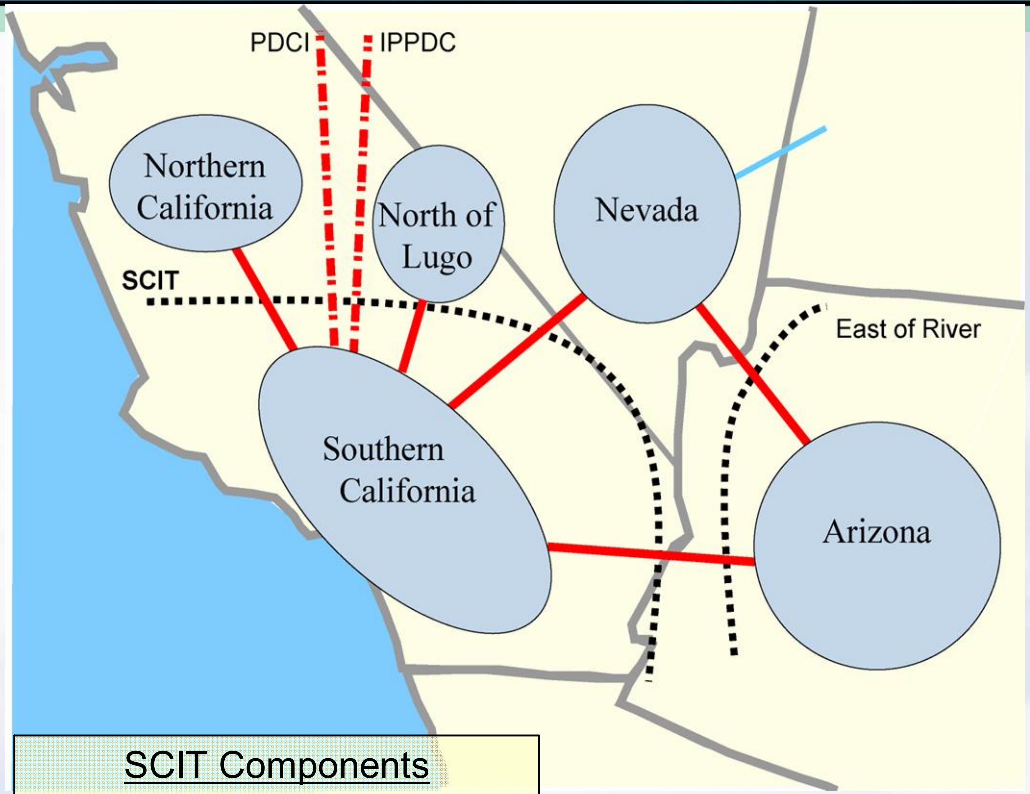
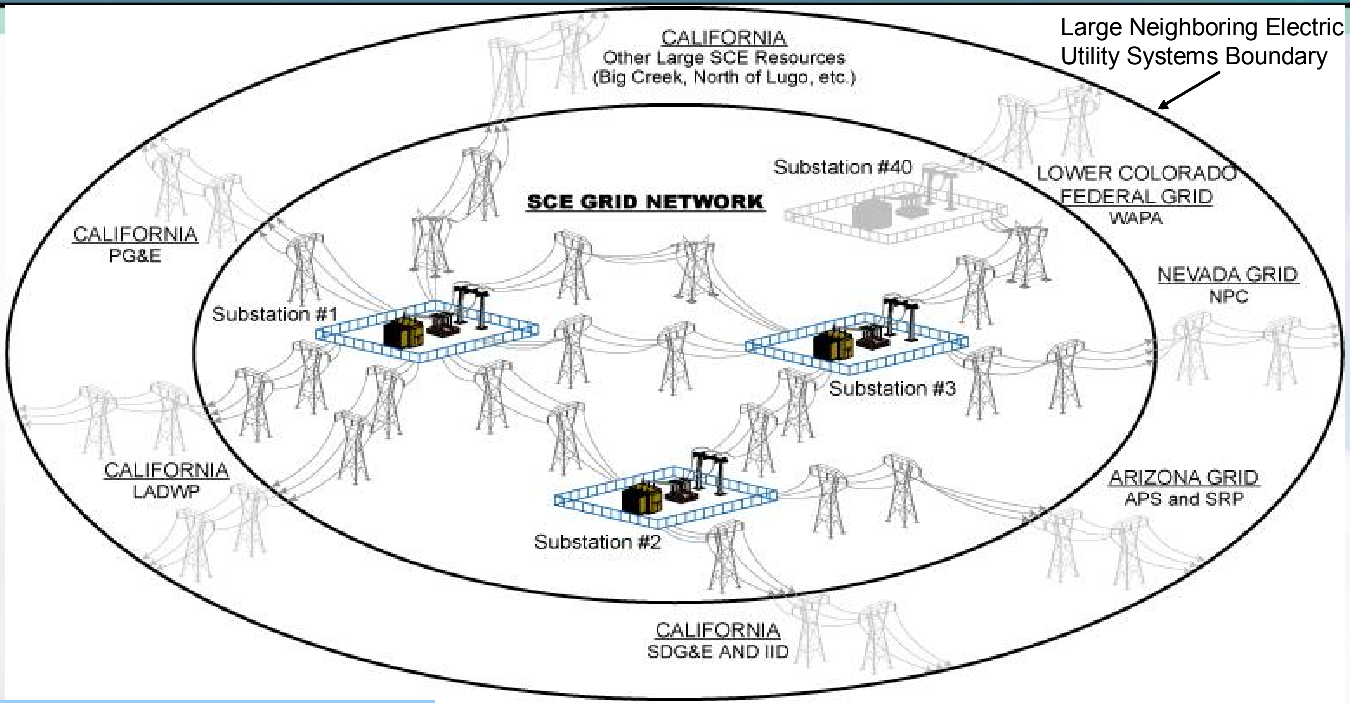
Southern California Import Transmission (SCIT)

- Summer 2007 SCIT total import capability will be 16,100 MW.
  - 500 MW increase over 2006
- It is limited by the loss of two SONGS units.
- Increase due to Valley voltage support and additional generators.



SCIT Components
- Midway-Vincent
- Pacific DC
- Intermountain DC
- North of Lugo
- West of River

C-RAS Based New Grid Reliability Standards and Operations Approach



Existing Reliability Criteria Mgmt.

1. N-1 and N-2 line/transformer outages
2. Path 26 outage
3. Limited to within SCE Grid Network

Future Reliability Criteria Mgmt.

1. Impacts of disturbances in Neighboring Grid Network
   - Recent LADWP outages of DC line and loss of major load
   - Major SCIT import changes
2. Expected DOE/FERC Mandatory Reliability Standards (Aug. 2006)
   - Influence for incentives to achieve higher reliability
3. Critical N-3 outages (Going beyond N-2)
4. Fire and earthquake disaster impacts
5. Faster post disturbance load restoration

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