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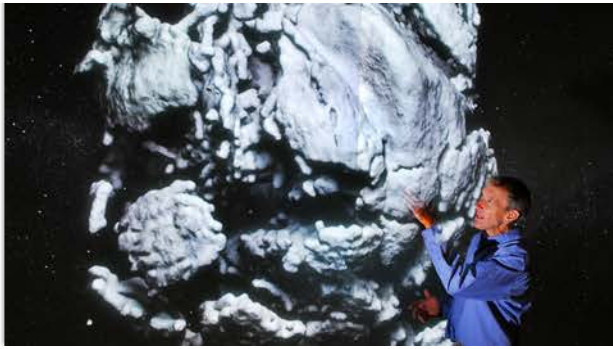

O&M Data Collection and Plant Optimization

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EPRI ELECTRIC POWER RESEARCH INSTITUTE

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Presentation Goals

- Understand the true benefits of **standardized O&M data collection strategies** for your project, and see how this could improve on-going performance
- Introduction to the PV Reliability O&M Database (PVROM) and data collection tool
- Case study: Determine the O&M benefits of string-level monitoring for your system and see how you can avoid costly loses in your plants output
- What's next: Standards development and upcoming workshops

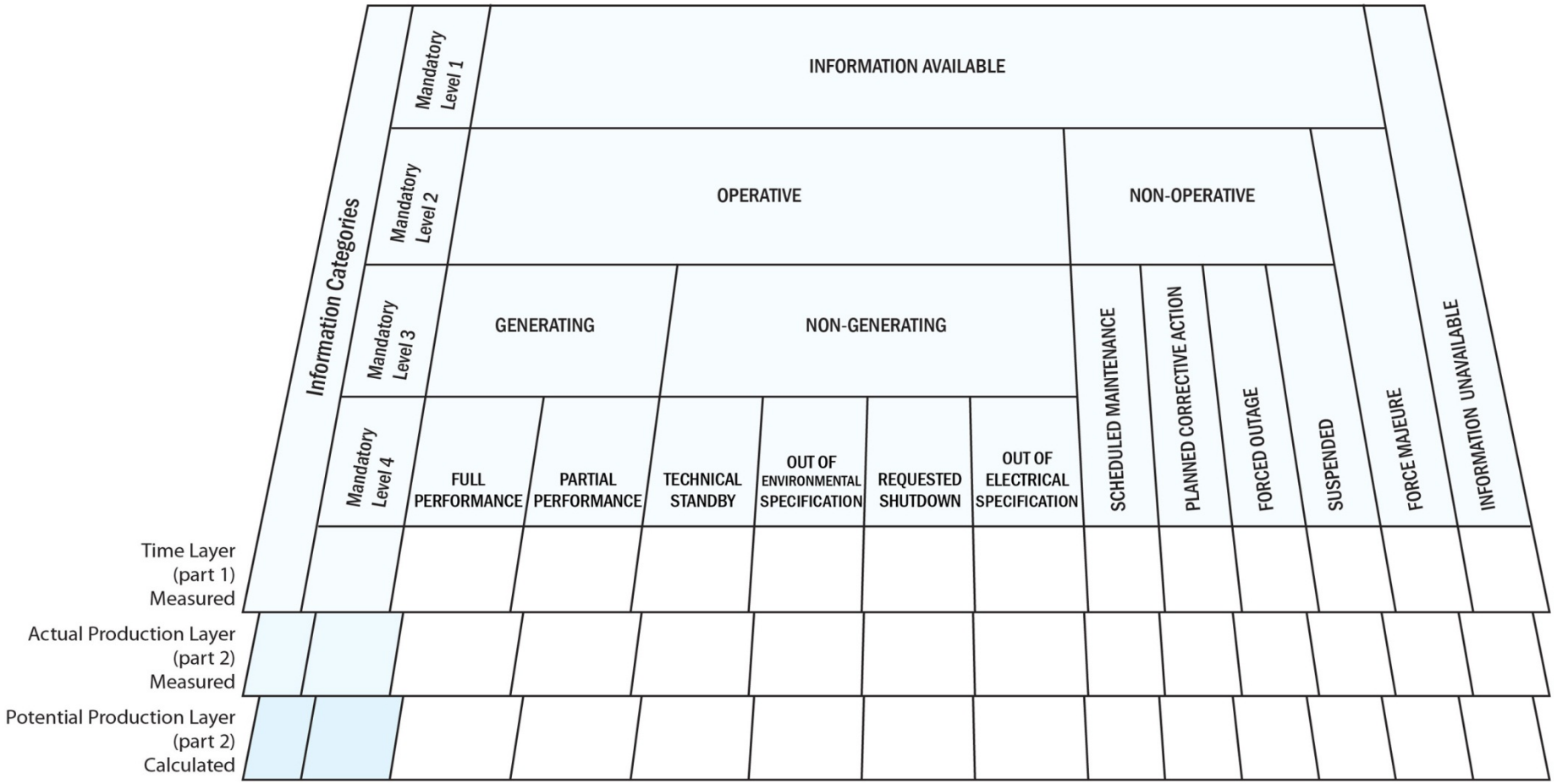
Standardized O&M: What are the benefits?

- What are the gaps today (industry-wide)
  - Standardization
  - Definitions
  - Reactive O&M versus Scheduled O&M
  - Moving from scheduled to condition-based O&M
  - Industry-wide quantification of O&M
- What are the impacts of the gaps
  - Uncertainty
  - Miscommunication
  - Higher cost of PV
  - Miscalculations of O&M requirements
  - Unplanned outages

Standardized O&M: What are the benefits?

- What are the benefits of standardization
  - Improved communication
  - Standardized reporting
  - Improved benchmarking for financial market assessments/predictions
  - Organized vs. ad-hoc
  - With better standards, the O&M provider has a better basis for tools, practices, procedures, and trained personnel
  - Added degree of confidence
  - Standards protect buyers and sellers, facilitate markets

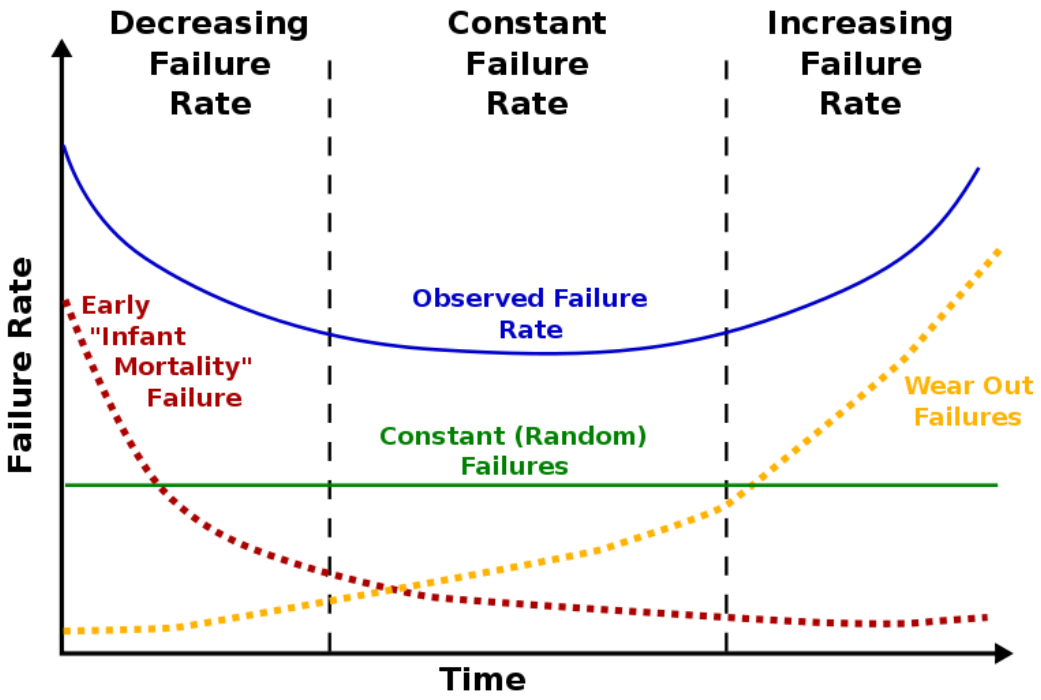
A Standardized Reporting Approach Facilitates the Market, Example of an Approach



IEC 61400-26

Collecting technical data to reduce risks and optimize predictability

- Common definitions and processes for tracking O&M events allows for aggregation of data sets
- Standardized reliability and financial reporting



The Problem with Risks

- There is a need to quantify risks for the financial community: production, operational, reliability
- There is a need to quantify risks no matter what community
- Cost of capital ∝ risk ∝ 1/knowledge
- This market is still relatively new
- Lower risks = lower costs = Sunshot goals = higher revenue

RAM: Reliability, Availability, Maintainability *System level reliability and availability estimates are required to facilitate cost tradeoff studies associated with competing photovoltaic systems. RBD models can assist---*

- *Estimates of reliability are necessary in developing maintenance cost projections over the system lifetime.*
- *Availability estimates provide an input into annual energy generation projections.*

Goals and Objectives Of O&M Projects

- EPRI and Sandia will focus on identifying and analyzing the technical risks involved in PV operation and maintenance
- Develop a growing partner base with solar industry stakeholders through formalized agreements with organizations and individual companies
- Facilitate increased, accelerated, and broadened data flow
- Integrate Sandia PV Reliability and EPRI Solar research through research data and combined performance reporting of the accelerated industry partnership data.

O&M Data Collection

- PV System ownership is a cradle-to-grave commitment
- Different Elements of O&M Data Collection
  - System monitoring; focused on tracking performance and production
  - Incident tracking; focused on tracking downtime and documenting failures/failure modes
  - Cost tracking; focused on documenting expenditures
  - Work orders; focused on managing response to O&M
- Predictability is critical to controlling costs and optimizing production. Tracking O&M is critical to predictability.

Technical Challenges

- Getting industry data, much of which will be considered to be competitive advantage
- Making it easy to provide data
- Working through standard practices, definitions, and reporting by industry operators. Setting the stage for industry to fulfill this function on own
- Aggregating reporting for baseline metrics

Why do we think tracking O&M is important for PV asset managers?

- Now have fleets of PV systems
  - Uniform organizational investment strategy
  - Uniform performance tracking strategy
  - Different geographical locations (and organizational regions)
  - Common annual fiscal process requires well documented proposals
  - Common (corporate) benchmarking of system production
  - Multiple business models for ownership of PV systems
- Responsibility to customers to employ rigorous O&M strategies that provide optimal return on investment

Why are EPRI/Sandia interested in tracking O&M data?

- Sandia has developed a set of linked reliability tools that are data driven—we need more data!
  - PV Reliability Operations & Maintenance (PVROM) database
  - PV Reliability & Availability Model (PVRAM)
  - PV Reliability and Performance Model (PVRPM)
- Sandia's reliability tools focus on developing accurate science/statistics-based predictions of system "ownership metrics"
  - field-based operations data + accelerated life test data
- Provide documented guidance to the community on efficiently run PV plants:
  - reduce risk of early equipment failure
  - reduce unscheduled downtime
  - optimize plant performance
  - control costs

Data Collection Tool

SNL's PV Reliability O&M (PVROM) Database

- Web-based incident (failure) reporting, analysis, and corrective action system software package (ReliaSoft's XFRACAS™)
  - FRACAS (Failure Reporting, Analysis and Corrective Action System) is a process for reporting, classifying, analyzing failures, and planning corrective actions in response to those failures
- Supports acquisition, management and analysis of system quality and reliability data from multiple sources
- Database resides on Sandia Restricted Network (SRN) server
- Access to database is through Sandia Open Network (SON)
  - Access restrictions (login ID and password) ensure only source users (partners) can access database
  - SNL issues SON login ID and passwords
  - Only system owner and EPRI/Sandia will have access to O&M data
- XFRACAS™ source permissions ensure source users can access only their own data
- XFRACAS™ platform supports both real-time and legacy failure/suspension (or non-failure event) data acquisition
- Supports incident record searches and report generation
- Supports export of data to ReliaSoft reliability life data analysis and reliability growth analysis software products
- Program partners may use other XFRACAS™ capabilities as well (e.g., failure analysis, corrective action tracking, etc.)

Data Needs for Reliability, Availability, O&M Optimization Analysis

PVROM Standard Dataset	Reliability	Availability	O&M
Incident Occurrence Date/Time	X	X	X
Bill of Material Part Number	X	X	X
Part Serial Number	X	X	X
Part Commissioning Date	X	X	X
Incident Description	X	X	X
Incident	X	X	X
Service Response Date/Time			X
Service Completion Date/Time	X		X
Restoration to Duty Date/Time		X	X
Energy Lost (kWh)	X	X	

Note that this is O&M data not unlike what is typically collected for most plant-like equipment.

PV System Bill of Material

Starting point for collection and analysis of performance data – one BOM for each system power block (data entry structure based on understanding of system architecture from reliability perspective)

Level	Part Number	Part Description	Part Version	Serial Number	Quantity	Build Date	Ship Date	Catalog	Manufacturing Code
1	SGSSS	SGS Solar System Power Block		SGS-1	1	07/13/2001			
2	TXL	480V/34.5kV Transformer		SCL-2	1	07/13/2001			
2	TXS	208V/480V Transformer		TXS-1	1	07/13/2001			
2	ADS	AC Disconnect Switch		ADS-1	1	07/13/2001			
2	DDS	DC Disconnect Switch		DDS-1	1	07/13/2001			
2	ECON	Array Electrical Connections		ECON-1	1	07/13/2001			
2	INV	Inverter		INV-1	1	07/13/2001			
2	LIGHT	Lightning Event		L-1	1	07/13/2001			
2	MOD	PV Module		M-U1-1	1	07/13/2001			
2	MOD	PV Module		M-U1-2	1	07/13/2001			
2	MOD	PV Module		M-U1-3	1	07/13/2001			
2	MOD	PV Module		M-U1-4	1	07/13/2001			
2	MOD	PV Module		M-U1-5	1	07/13/2001			
2	MOD	PV Module		M-U1-6	1	07/13/2001			
2	MOD	PV Module		M-U1-7	1	07/13/2001			
2	MOD	PV Module		M-U1-8	1	07/13/2001			
2	MOD	PV Module		M-U1-9	1	07/13/2001			
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2	MOD	PV Module		M-U1-11	1	07/13/2001			
2	MOD	PV Module		M-U1-12	1	07/13/2001			
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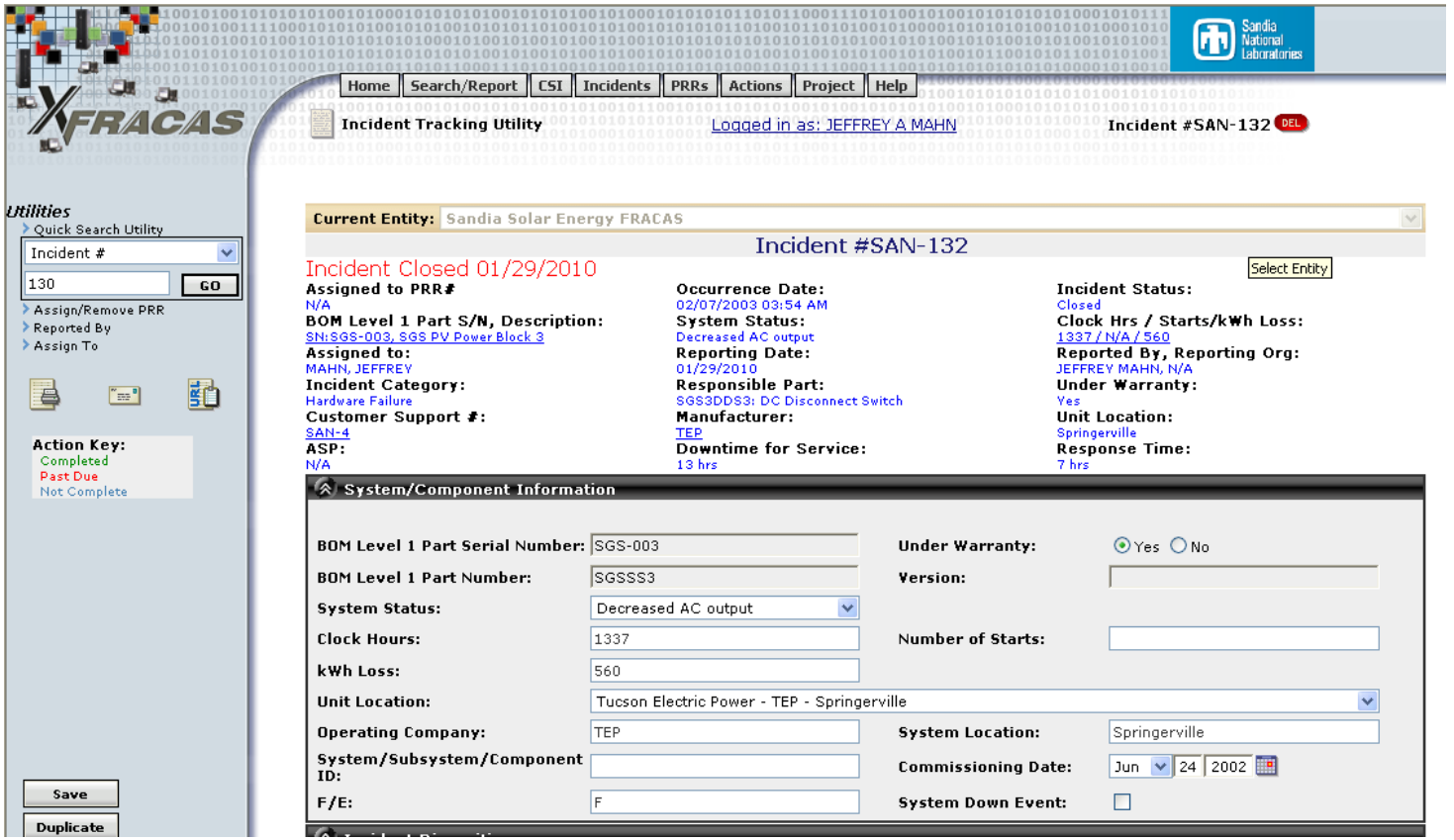
2	MOD	PV Module		M-U1-19	1	07/13/2001			
2	MOD	PV Module		M-U1-20	1	07/13/2001			
2	MOD	PV Module		M-U1-21	1	07/13/2001			

EPRI/Sandia can assist in developing facility/installation BOMs.

Performance Data Entry (SAMPLE)

…. and elaborated upon with XFRACAS™ Incident Tracking Utility



Initial incident data and incident status updates would be entered by O&M personnel at each site.

Additional XFRACAS Features and Analysis Opportunities

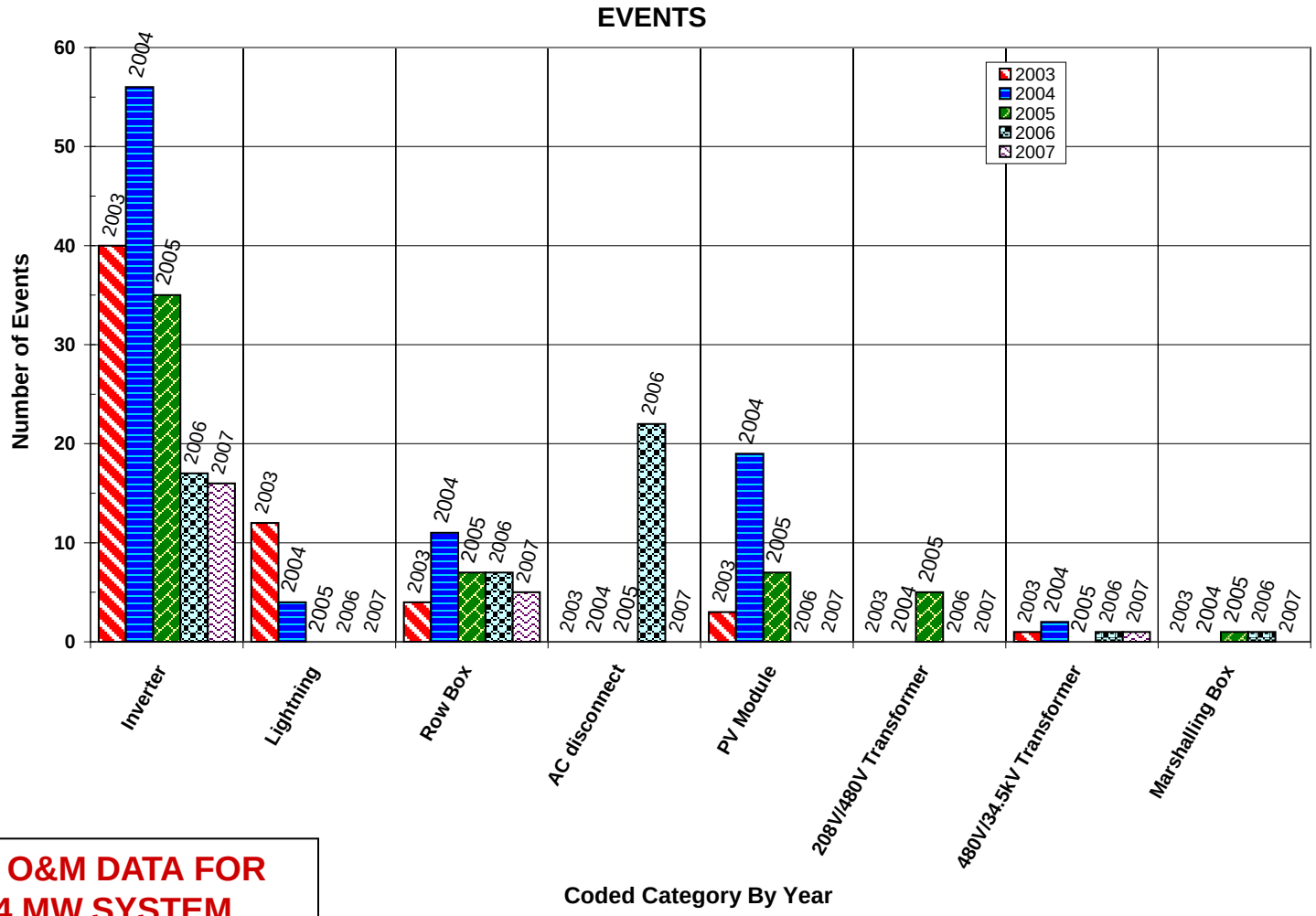
Program partners may use other XFRACAS™ capabilities as well:

- Imports of historical incident data
- Responsible individual email notification of incident creation/updates
- Labor hours and non-labor costs can be recorded in incident records
- Generation of database queries and reports
- Legacy data can be entered into PVROM using an Excel spreadsheet format

SNL and EPRI make use of data analysis:

- Data is easily exported for reliability analysis
- Using XFRACAS™ allows SNL and EPRI to perform reliability analyses using other ReliaSoft tools without further manipulation of data

Example: Summary of PVROM Component Failures



5 YEARS O&M DATA FOR FROM A 4 MW SYSTEM

Partnership Roles

- PV system owner adoption of the PVROM database includes:
  - Developing BOMs for each PV facility/installation
  - Entering PV system event data into the PVROM database (ongoing activity) with continuous accessibility to data
  - Providing available PV system legacy data if available
- EPRI/Sandia will provide necessary PVROM training
  - Assistance in developing necessary BOM's for PV facilities/installations
  - Assistance, as needed, with data collection/entry issues
  - Assistance entering PV system legacy data into PVROM
  - Perform reliability/availability analysis for PV system data and providing results to system owner
- Reliasoft provides additional training on the use of XFRACAS™

Why?

- The importance of PV System O&M should not be understated
  - There are different elements of O&M and the importance of tracking these on PV systems is significant
  - The value of tracking O&M on PV systems has operational, performance, and economic implications
  - EPRI/Sandia's intend to acquire additional data to further develop reliability tools
- Use of the PV Reliability O&M (PVROM) database is straightforward and relatively streamlined
  - Access requirements
  - System BOM creation
  - Data entry
- PVROM is founded on collaborative partnerships between EPRI/Sandia and partners

Motivation

- Accurately predicting long-term performance is challenging but necessary to assess financial viability and risk
- PV plants are complex interconnected systems with thousands of components
- Important factors for modeling PV systems include:
  - » Location, technologies, and system design
  - » Weather and solar resource variation
  - » Degradation and component reliability
  - » Operations and maintenance strategies

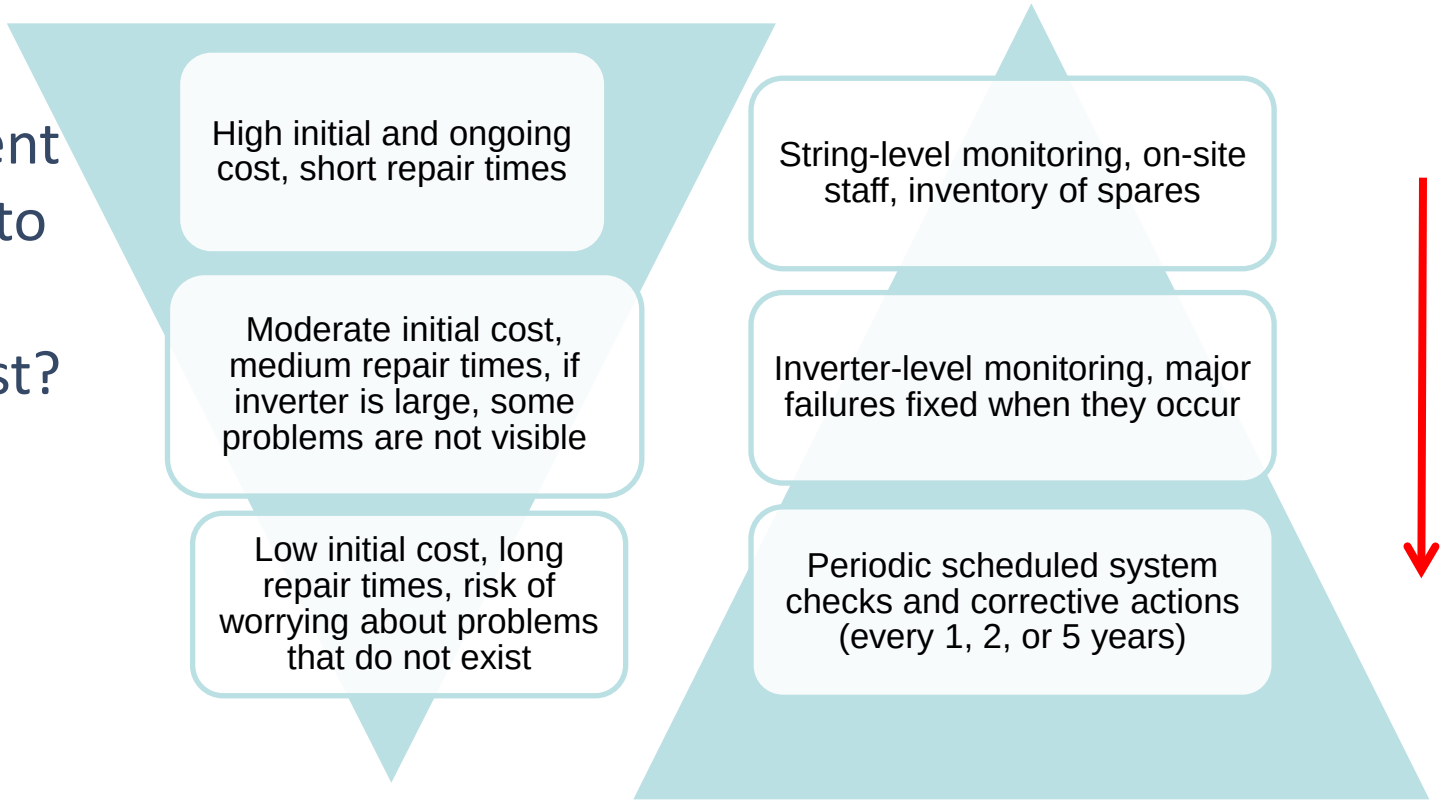
Case Study: Which O&M Approach?

Assumptions:

- 16.4 kW system at latitude tilt in Fort Worth, TX
- 96 poly-Si modules in 8 strings of 12, 170 W modules
- Three inverters modeled as single-point efficiency inverters (94% efficiency)
- Failure rates and distributions based on real-world examples
- The simulations were run for 30 years using an hourly time step. We ran 100 stochastic realizations.
- Soiling was assumed to negligible; module degradation rate of 0.5% per year.

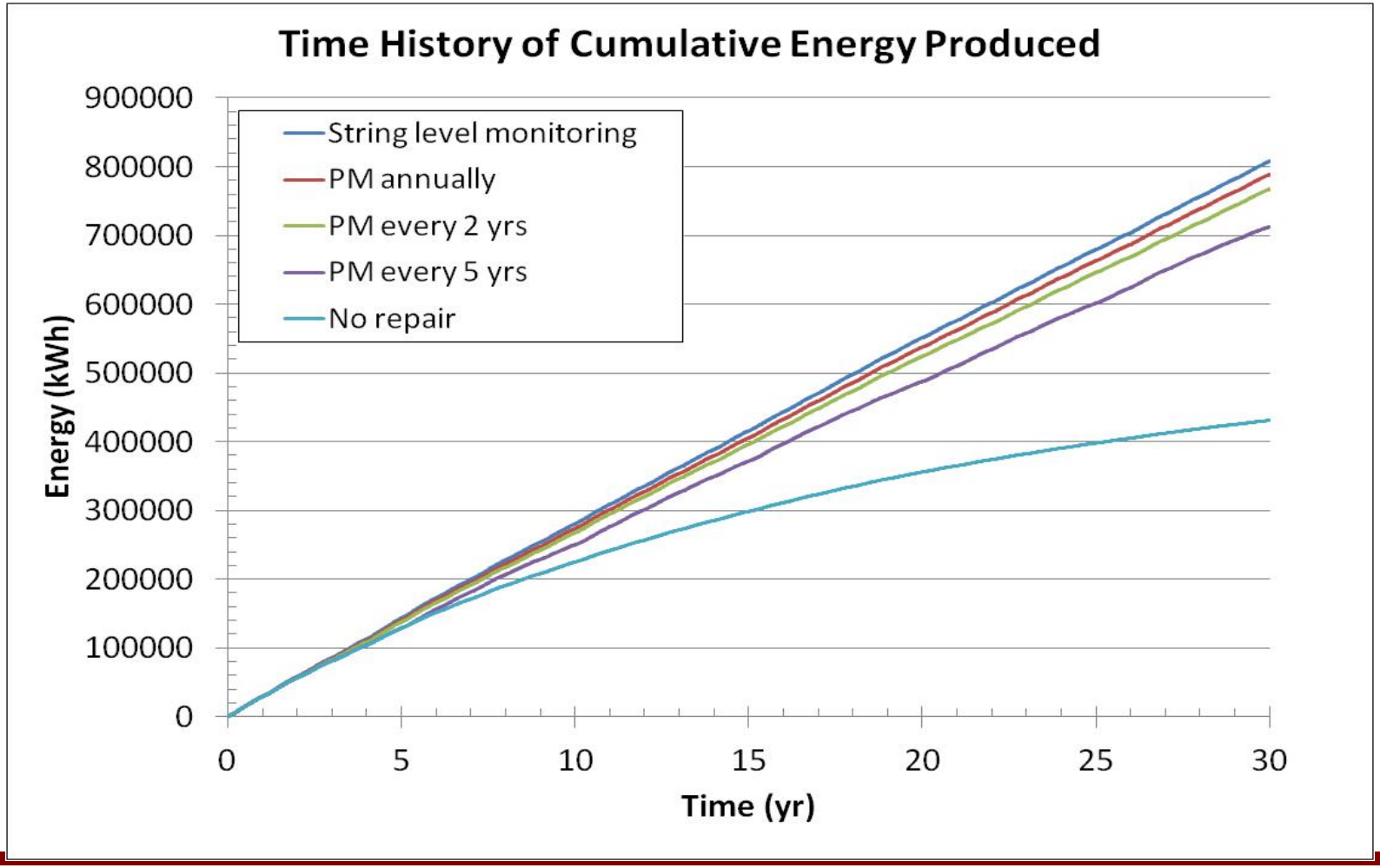
Case Study: Which O&M Approach?

There are different O&M strategies to consider.
Which one is best?



Case Study: Which O&M Approach?

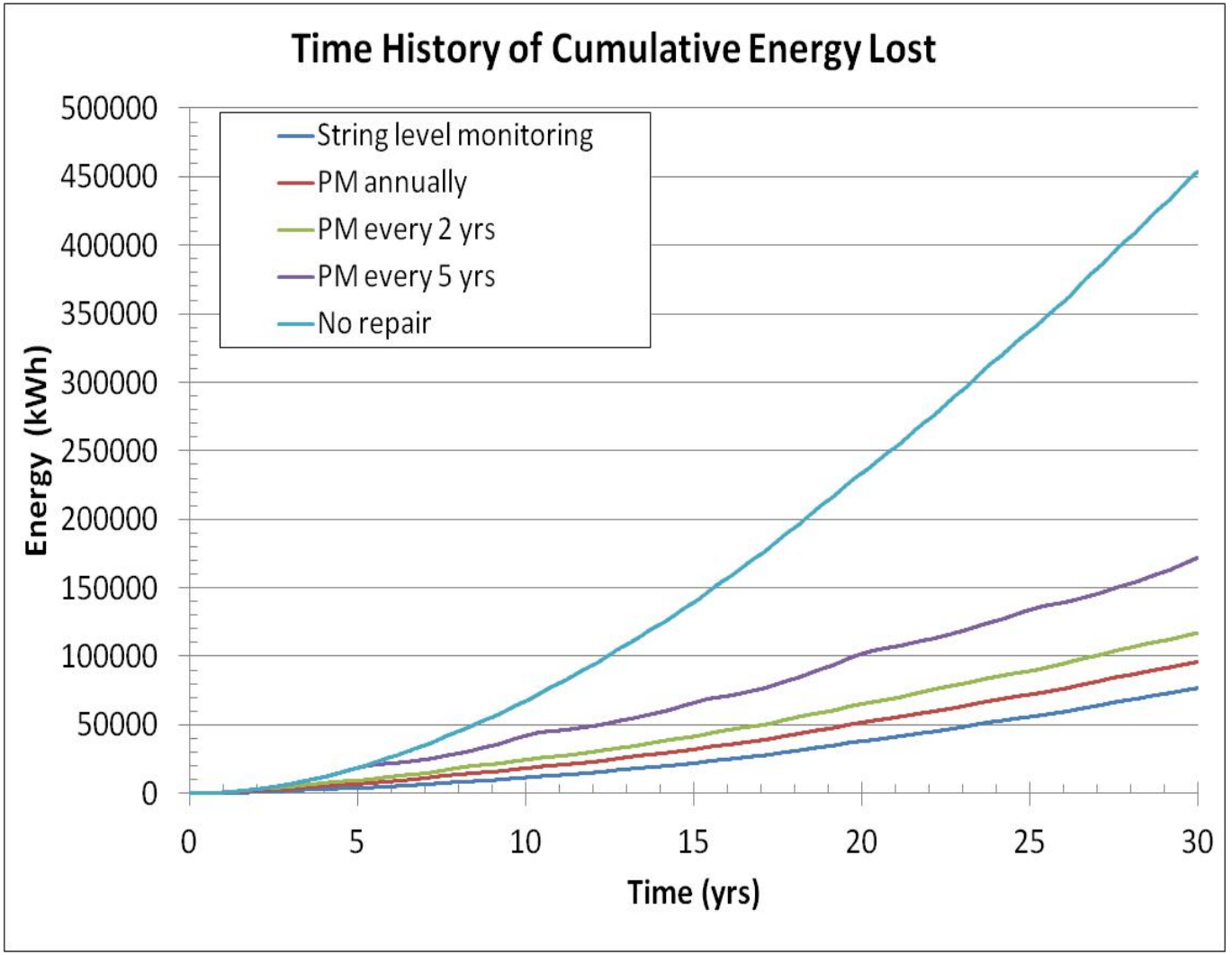
The resulting energy produced from these scenarios can be evaluated.



Case Study: Which O&M Approach?

The energy lost due to failures can add up over the life of the system

There is a tradeoff between performance and cost of O&M



Summary

- Reliability and O&M is an important factor in determining performance and profitability of PV plants
- Coupling performance, reliability, and financial modeling into one tool allows evaluations of different O&M strategies, different system designs, and different technologies
- PV project bankability is enhanced if system performance is well understood and the uncertainties are known

What are the metrics for success?

- $$$
- O&M costs accurately identified
- Production metrics = MWhrs, Capacity factor, revenue
- Reliability metrics = reliability, availability, maintainability, MTBF, MTTR, lost energy, costs
- Bankability, technical risk defined, best practices and standards, risks mitigated in the financing costs
- Transactional costs reduced

Success looks like:

- Mutually beneficial industry participation
- Regular industry feedback, workshops and symposia
- Statistically significant data that accurately characterizes the technical risks
- Information treated properly
- Baseline performance made transparent
- Establishment of industry approaches to continue select functions for market sustainability

Future Work

- Expand the database: new partners
- Facilitate development of O&M industry standards
  - Standard definitions
  - Best practices
  - Data collection guidelines
- Upcoming EPRI/Sandia O&M Workshop
  - **Date:** 8:00 AM to 5:00 PM on Monday, April 29, 2013
  - **Location:** EPRI Headquarters at 3420 Hillview Avenue, Palo Alto, CA
  - **Focus**: *Solar PV O&M drives project life cycle costs and plant performance. What tools and techniques—combined with data analysis—can lead to operational improvements and best practices? This **actionable workshop** will share perspectives and findings, as well as establish a Working Group tasked with developing a robust set of industry-wide PV O&M standards and protocols.*
- Develop a PVROM Users Group

Helpful References

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