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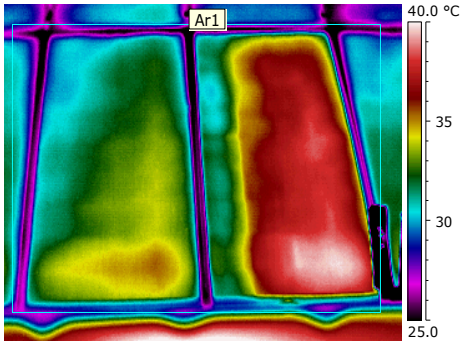

Sandia National Laboratories
Photovoltaic and Grid Integration Dept.

Solar ABCs Stakeholder Meeting

October 23, 2014 Las Vegas, NV

Roger Hill, Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

SunShot U.S. Department of Energy

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Sandia's Work in O&M Related Standards

OBJECTIVES

- Improve O&M Best Practices
- Participate in and develop new O&M standards
- Mitigate PV system performance and financial risk by improving our knowledge of how reliability impacts O&M activities

APPROACH

1. Collect PV system event data
2. Determine gaps and what groups are addressing certain areas
3. With working group, develop best practices that fill these gaps. Preventative maintenance, Availability-fault & failure analysis-data collection-key performance indicators
4. Actively participate in ASTM ICOMP and IEC Maintenance standards development
5. Submit Sandia working group efforts to Standards body (IEC) on Availability-fault and failure analysis-data collection-key performance indicators (KPIs)
6. Periodic Workshops and outreach

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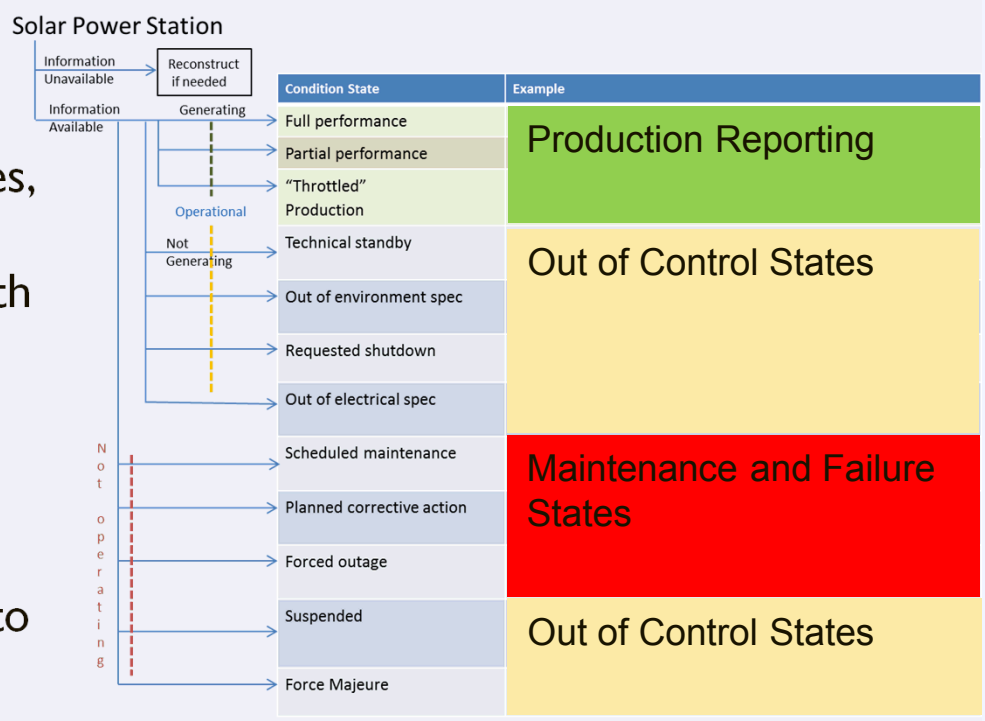
Precursor Report of Data Needs & Recommended Practices for PV Plant Availability, O&M Maintenance Reporting

Led by Roger Hill, in consultation with Sandia O&M Working Group

Goal - Provide descriptions of quantitative numerical metrics of PV plant performance, including clock time of failures, faults, restoration times, other outages and lost energy and related two way effects with the plant operational and maintenance (O&M) function

Objectives - ensure that a PV system will be ready as needed, will perform as intended and can be optimally maintained to be as close to fully-operational during its lifetime (embedded in reliability definition)

Includes: Data needed, KPIs, report format, NERC GADS, O&M, Availability



The good, the bad, and the ugly

Good: O&M service providers engaged

Bad: Availability definitions are enigmatic, spastic, and problematic

Ugly: O&M Service providers charged with liquidated damages if the plant they didn't specify, design or install underperforms

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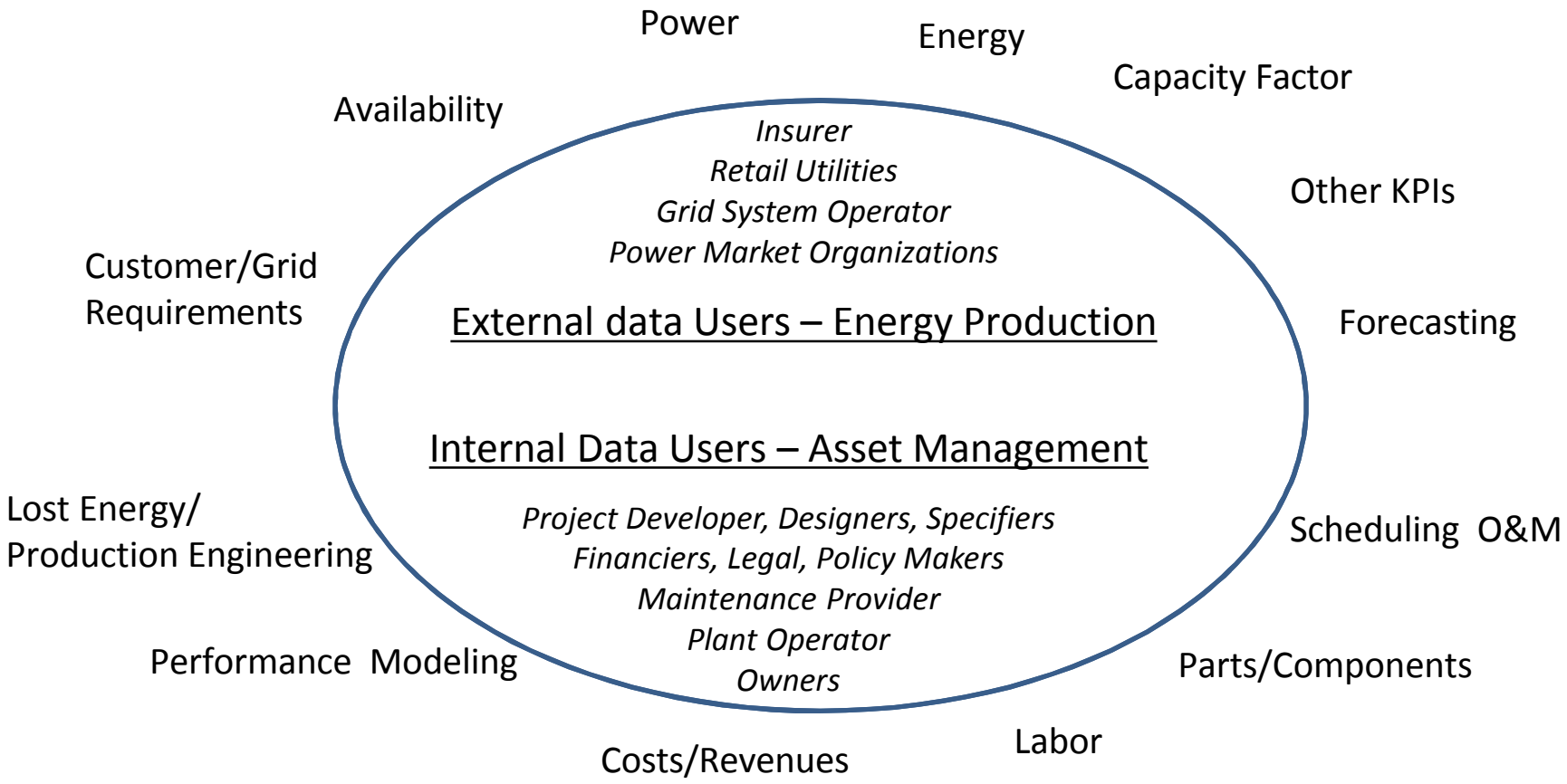
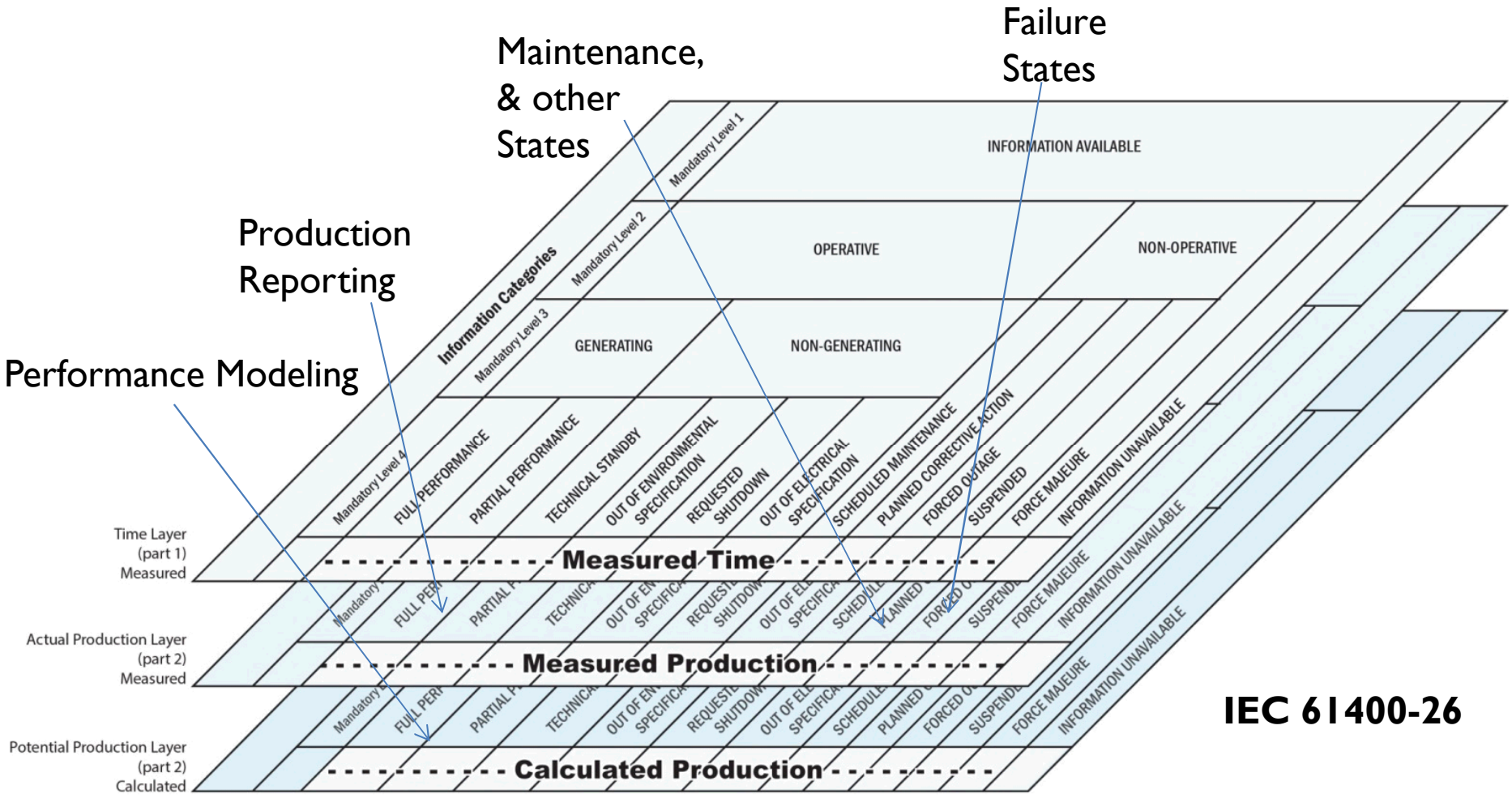
Data Users and Types (stakeholder analysis illustration)



Availability States



*A common basis for information exchange on performance indicators between owners, utilities, lenders, operators, manufacturers, consultants, regulatory bodies, certification bodies, insurance companies and other stakeholders in the wind power business. It is used to help define requirements to support clear understanding of contract terms.

Condition State	Example
Full performance	Function with no limits or restrictions
Partial performance	Functioning with limitations and/or restrictions
Technical standby	Temporarily nonfunctioning due to controlled and/or predefined tasks required - e.g. self-testing, ramp-up
Out of environment spec	Operative but not functioning as the environment is out of design specs
Requested shutdown	Operative but stopped by an external request-i.e. curtailment
Out of electrical spec	Operative but not functioning as the electrical parameters are out of design specs - i.e. grid outage
Scheduled maintenance	Scheduled maintenance prevents system components for performing the intended functions
Planned corrective action	Actions required to retain, restore, or improve the intended functions that are not part of normal scheduled maintenance
Forced outage	Action taken as unforeseen damage, faults, failures or alarms are detected
Suspended	Activities in SCHEDULED MAINTENANCE, PLANNED CORRECTIVE ACTION and FORCED OUTAGE are interrupted or cannot be initiated due personal safety or equipment integrity - e.g. extreme weather
Force Majeure	Extraordinary event or circumstance beyond the control of the parties, prevents the parties from fulfilling their obligations.

Some Insightful Definitions (among many)

Predicted Energy: The energy generation of a PV system that is calculated with a specific performance model, using *historical* weather data that is considered to be representative for the site. (IEC 61724)

Expected Energy: The energy generation of a PV system that is calculated with a specific performance model, using actual weather data collected at the site during operation of the system. (IEC 61724)

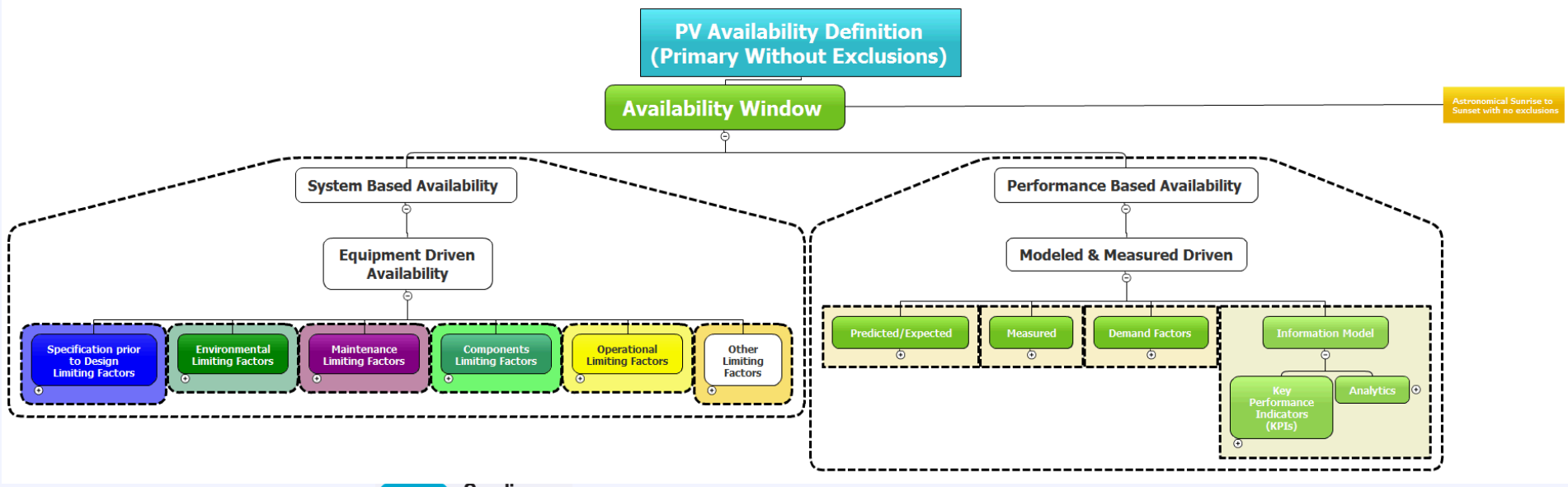
Operational Availability: Primarily an operator's or user's view of a system as a whole and measures how the asset was actually generating power and revenue (IEC 61400-26-1)

Technical Availability: Primarily a manufacturer's view and measures how often the system/component operated as is was intended to operate (lost production due to maintenance as specified, environmental conditions outside of the specification, standby for internal checks, etc. are not considered as unavailable (IEC 61400-26-1)

PV O&M Working Group, continuing…

- Started in FY 13 to address reliability and O&M topics
  - We've met 13 times in FY 14, averaging 17 participants per meeting. Good representation of members from across industry
  - Providing invaluable insight with Gaps Analysis, Reliability | Availability | Data reporting | KPIs paper, and Availability flow charting

Availability is a large gap, in terms of how it's defined in contracts, and impacts to performance



Roger Hill, rrhill@sandia.gov

Summary:

- Faults in systems and failures of components affect availability
- Unavailability requires maintenance.
- Unavailability affects production negatively.
- Lost production affects revenues.
- Best practices and standards clarify requirement needs and expectations.

How? By providing a common basis for information exchange on performance indicators between and among stakeholders. They can be used to help define requirements to support clear understanding of contract *terms.*