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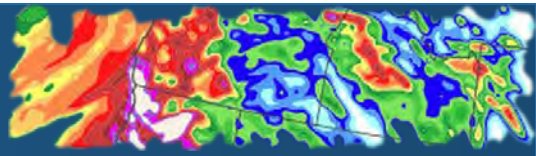
Maintenance Management Best Practices for Data Collection Networks



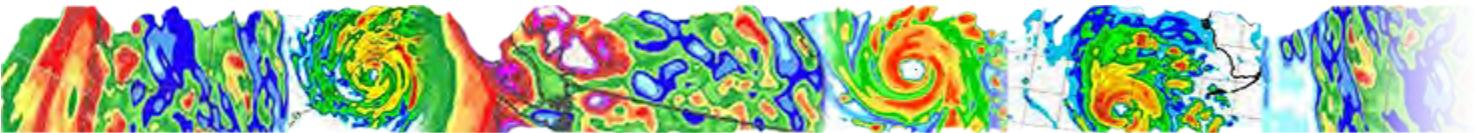
Mike Zucosky, Director of Operations

James Logan, CEO

Experts measuring rainfall and its consequences™

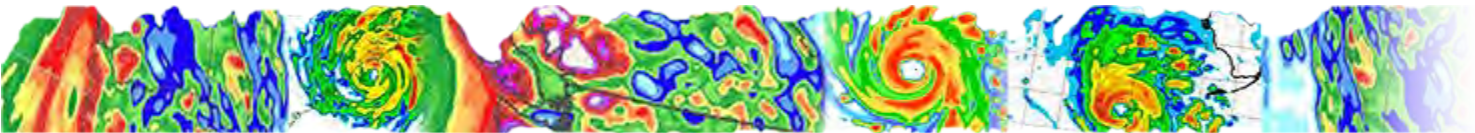
Understanding Maintenance Types

- Traditionally, maintenance activities occur on a regularly timed interval or are reactions to breakdowns
  - **Preventative Maintenance**
  - **Corrective Maintenance**



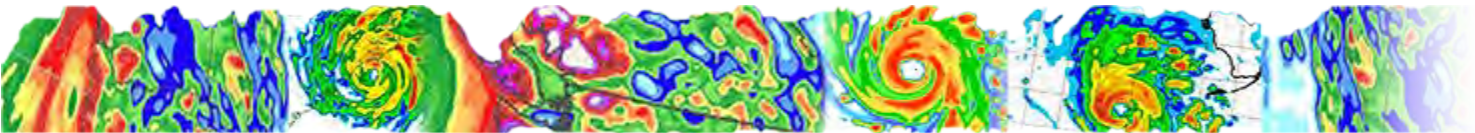
Understanding Maintenance Types

- **Preventive Maintenance**: Maintenance performed on a time basis, with regularly occurring intervals
  - Avoid consequences of gauge failure by replacing/repairing components before they fail



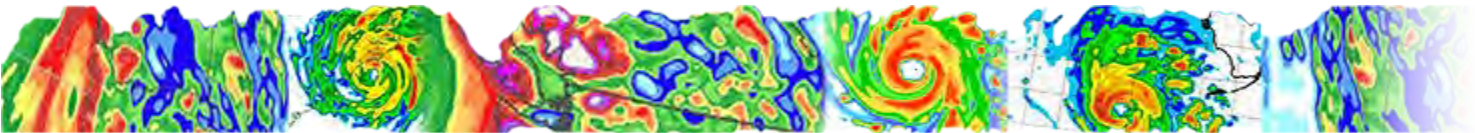
Understanding Maintenance Types

- **Corrective Maintenance**: Repairing equipment which has failed
  - Reactive
  - Typically experience down time



Understanding Maintenance Types

- Knowledge based maintenance types
  - **Project Maintenance**
  - **Predictive Maintenance**



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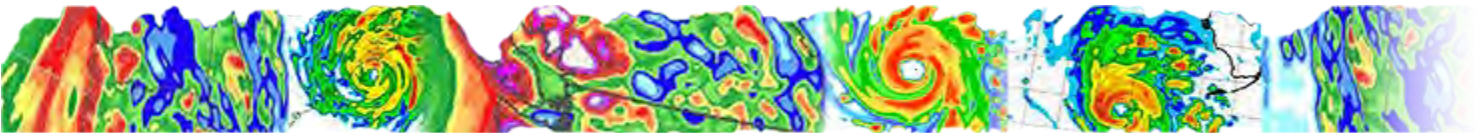
Understanding Maintenance Types

- **Project Maintenance**: Identify areas of weakness in your system, and develop a path to increase robustness.
  - Examples:
    - Standardization of components
    - Accessibility
    - Standardization of maintenance procedures
    - Designing in system redundancy



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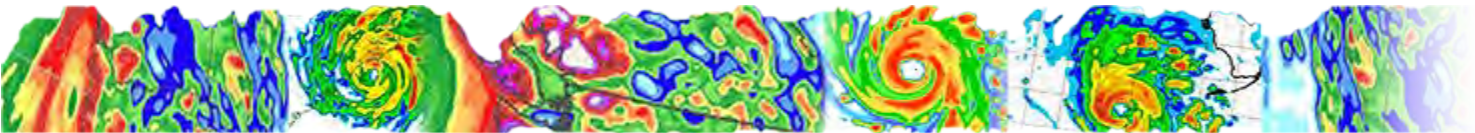
Understanding Maintenance Types

- **Predictive Maintenance**: Determine which gauges need attention and perform maintenance before corrective maintenance is required
  - Smart tools
  - Smart monitoring
  - Smart reporting



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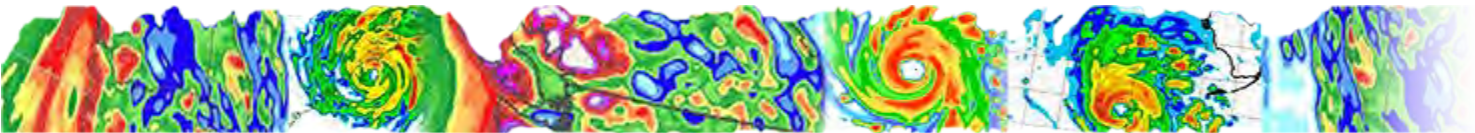
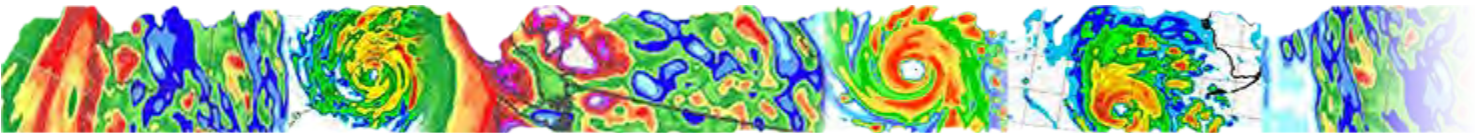
Understanding Maintenance Types

- With the right framework, it is possible to leverage the best of all of these
  - **Reliability Centered Maintenance**



Best of all Methods

- **Reliability Centered Maintenance**
  - Complete maintenance program that combines predictive, preventive and project maintenance
  - Proper predictive maintenance ->
    - Decreased preventive maintenance visits
    - Decreased breakdown maintenance
  - Increase reliability, limit number of gauge visits
    - Better data with less outages & reduced maintenance costs



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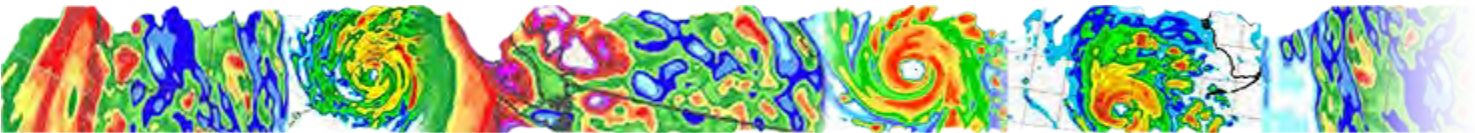
Reliability Centered Maintenance

- Effective reliability centered maintenance requires data analysis tools to spot trends in gauge and system performance
  - Sensor Data Analysis
  - Sensor Availability
  - Nearest Neighbor Comparisons
  - System/Network Level Analysis
  - Automated Alarming



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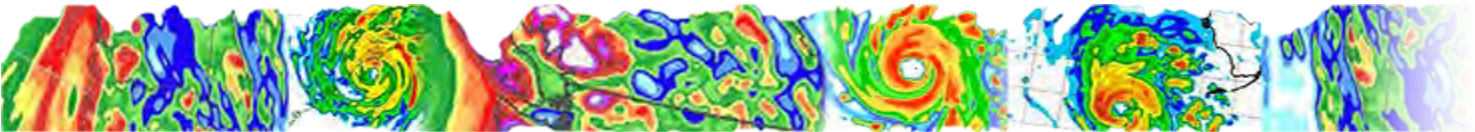
Reliability Centered Maintenance

- Sensor Data Analysis
  - Reports falling outside of defined data validation criteria vs. good quality reports
  - Over-Reporting Sensors
  - Sensor reports above/below a defined threshold
    - Last reported voltage less than 12.3V
    - Stage gauges with large changes over 24 hours

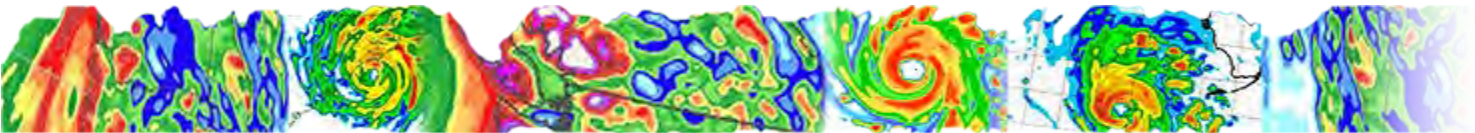


Reliability Centered Maintenance

- Sensor Availability
  - Sensors with no recent reports
  - Did we see the expected number of sensor reports?
    - » Based on timer interval and event data

# Reports	Availability %	Timer Interval
720	91.0	0:15:03
665	75.2	0:14:59
37	33.0	6:00:01
16	100.0	11:59:59

Timer Report Availability	Event Report Availability
50.0%	**78.2%**



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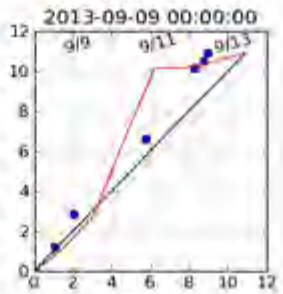
Reliability Centered Maintenance

- Nearest Neighbor Comparisons
  - Double Mass Analysis
  - Visual and tabular representation of rain gauge performance by comparing data to neighboring measurement locations.

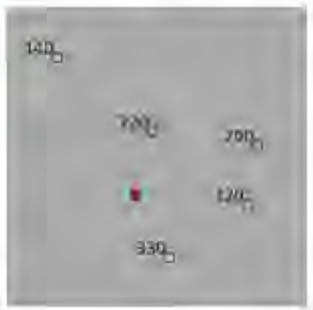
Table

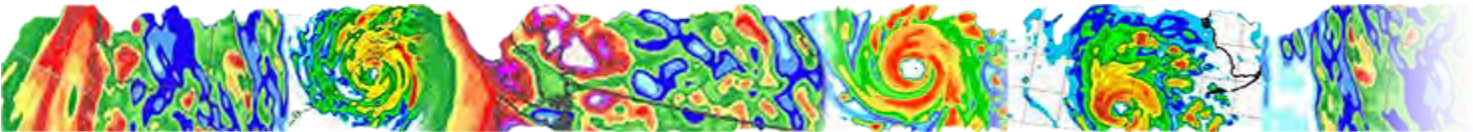
	Dist	Accum	#Rpts	Start	End
110	0.000	10.907	172	09/10/13	09/16/13
220	1.571	11.695	195	09/09/13	09/16/13
330	1.749	8.111	128	09/09/13	09/16/13
120	3.240	5.710	97	09/10/13	09/16/13
200	3.692	5.591	102	09/09/13	09/16/13
140	3.960	13.546	234	09/09/13	09/15/13

Plot



Map





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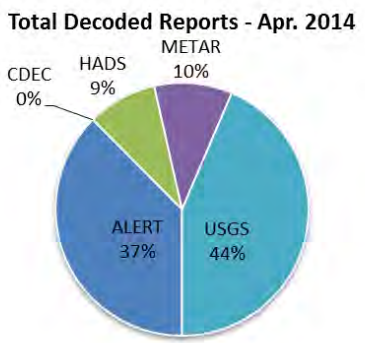
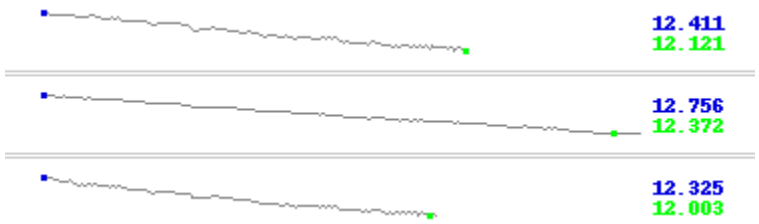
Reliability Centered Maintenance

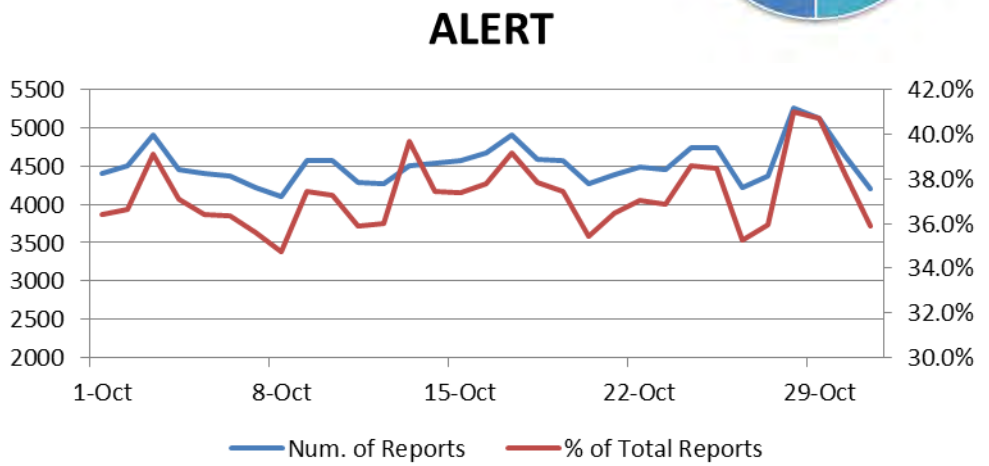
- System/Network Level Analysis
  - Performance through quality flag and report counts
  - Sparkline graphics

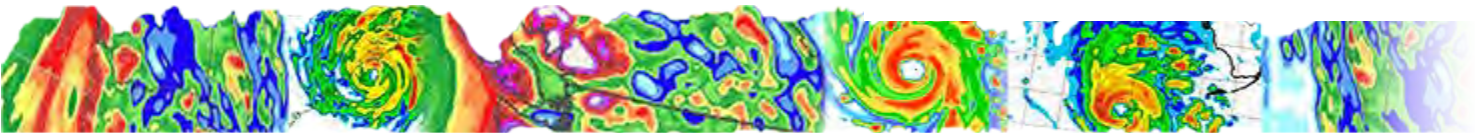


Data Quality

% of Good Data	98.07%
% of Invalid Data	1.93%
% of duplicate Reports	0.00%







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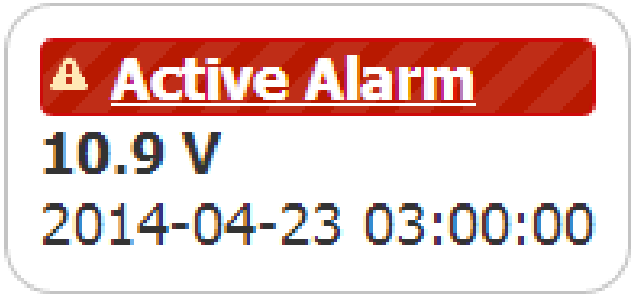
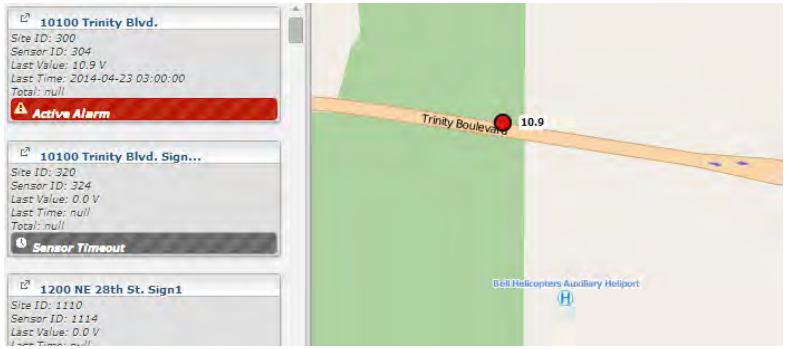
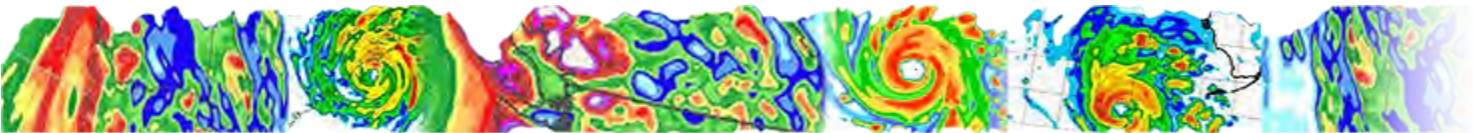
Reliability Centered Maintenance

- Automated alarms in your data collection software to enhance maintenance activities





Title	Equation	Site	Sensor	Enabled
Battery Low	(last_value() <= 11.5)	Kentfield	Battery voltage	☐
Low Voltage	last_value() <= 11.5	Novato Creek	Precipitation Battery	☑
Low Voltage	last_value() <= 11.5	Arroyo Corte Madera del Presidio	Battery voltage	☑



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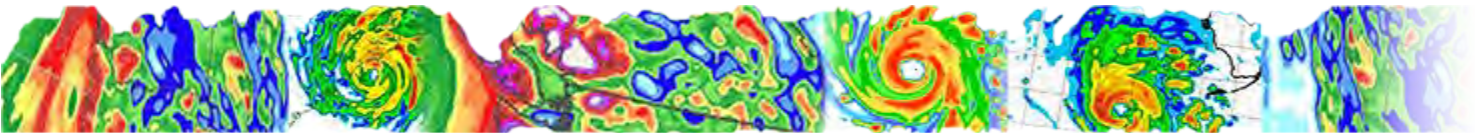
Tools and Capabilities

- Effective Reliability Centered Maintenance requires specialized tools:
  - Performance Reporting
  - Inventory Tracking
  - Maintenance Tracking
  - ALERT2 Specific Tools



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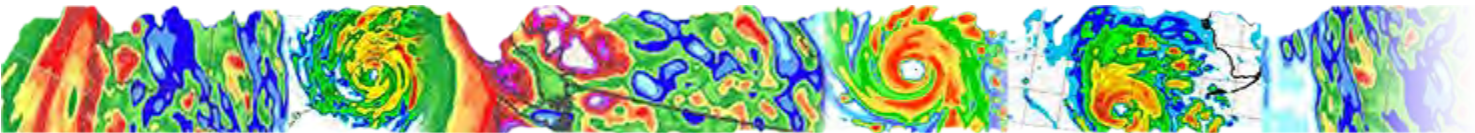
Performance Reporting

- Sensor performance
  - Standard reports
- Data analysis performance tools
  - Tools that do complex analysis
    - % Missing data records
    - Nearest neighbor analysis
    - Correlation analysis
- Performance Report Card



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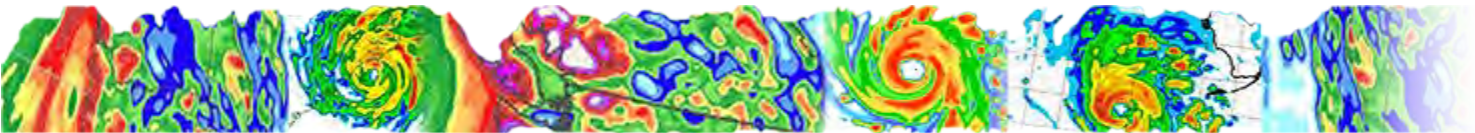
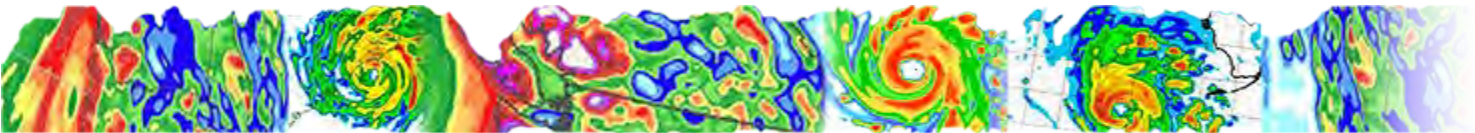
Inventory Tracking

- Inventory tracking support is vital
  - Knowledge of equipment, firmware, components needed before site visit
  - PT Failure Example: What do we need to know to efficiently replace the unit?
    - Cable Length, Output (4-20mA vs. 0-100mV), PSI range, etc.
  - This information reduces the need for multiple site visits



Inventory Tracking

- Historical information about components provides context for failure modes
  - Has this item failed before? Required an RMA previously? Require calibration updates more often than other units of the same model?
- Manuals and data sheets should be easily accessible
- Are sufficient spares available for upcoming maintenance activities?



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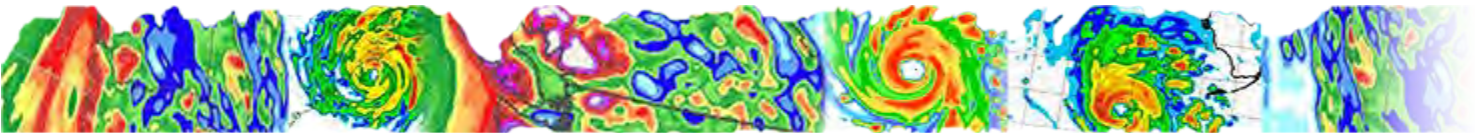
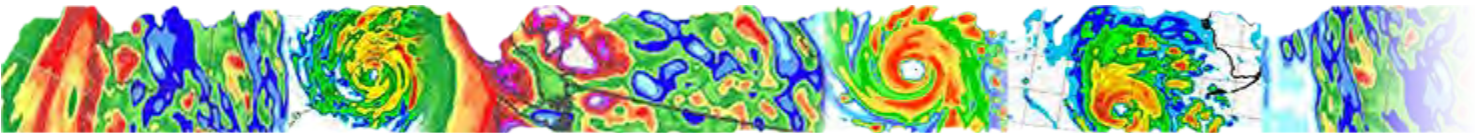
Maintenance Tracking

- Best practices in tracking maintenance activities include:
  - Standardizing maintenance procedures
  - Activity logs
  - Maintenance scheduling
  - Maintenance prioritization
  - Real-time access to work orders



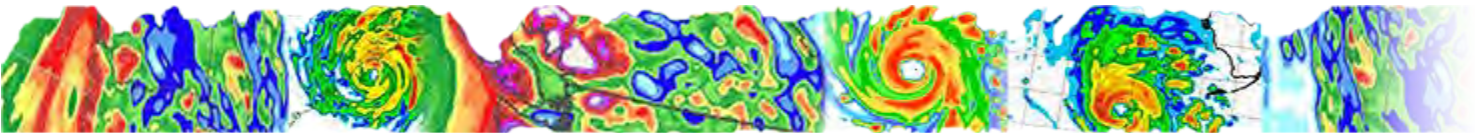
Maintenance Tracking

- Standardized Maintenance Procedures
  - Perform equivalent maintenance tasks across similar equipment
  - Well documented maintenance procedures
  - Tools to support standard practices



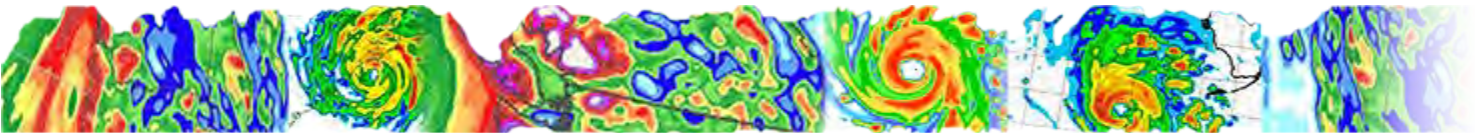
Maintenance Tracking

- Activity Logs
  - Work performed on an item or at a site location should be tracked and accessible to maintenance personnel
  - All maintenance history logged
  - This information should be made available to personnel in real-time and at remote locations if possible



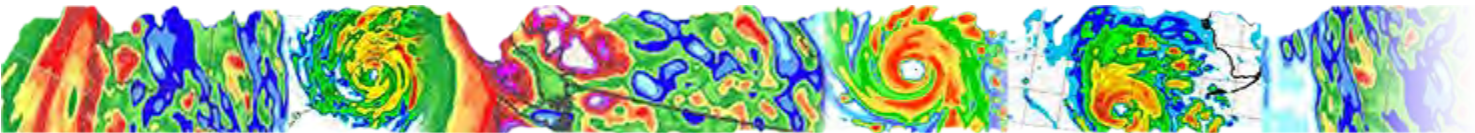
Maintenance Tracking

- Maintenance Scheduling
  - Assignment and tracking of all maintenance activities
  - Work orders
  - Calendars
  - What maintenance activities are overdue?



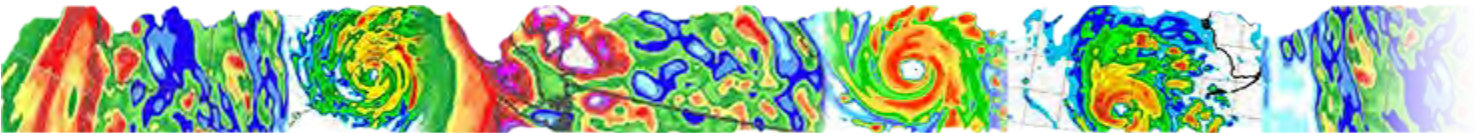
Maintenance Tracking

- Maintenance Prioritization
  - Work orders that constitute required emergency maintenance should be clearly identified
  - Status of higher priority maintenance
  - Status of both time and priority for all work orders



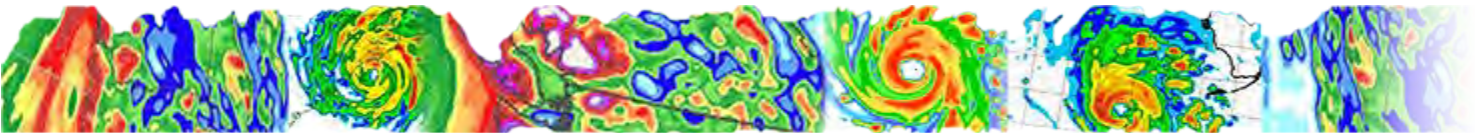
ALERT2 - Tools

- ALERT2 Time Slot Management
  - All time slots should be identified and an implementation order designed before the first gauge or repeater is installed
  - Consider the impact of other agencies sharing frequencies and network equipment when assigning time slots



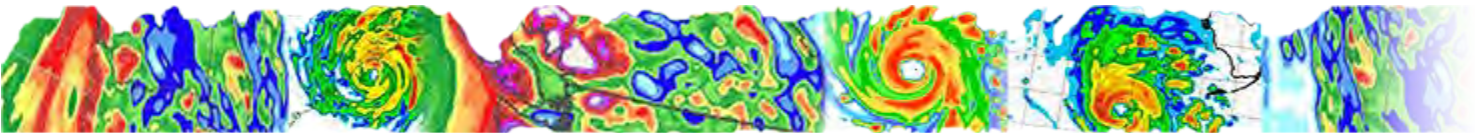
ALERT2 - Tools

- ALERT2 Field Decoder
  - Decode output on gage frequency
  - Decode output on repeater frequency
  - Verify site operation while at the site
    - Verify base station if remotely accessible
    - Verify through field decoder if not



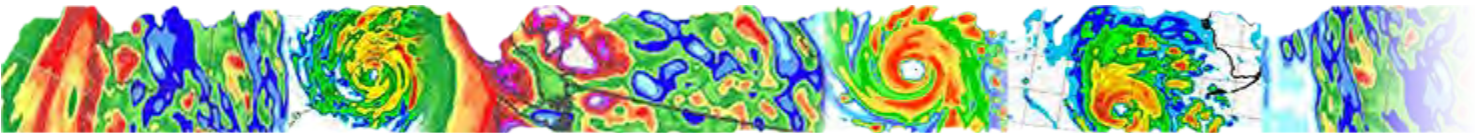
ALERT2 - Tools

- Inventory management of ALERT2 site configuration
  - Hardware
  - Firmware versions
  - Up loadable configuration files
  - Reference information for all settings
  - History of configuration changes
  - Track ALERT2 specific settings



Summary

- Reliability Centered Maintenance
  - Hybrid of Predictive, Preventive and Project Maintenance
- Smart tools for supporting maintenance
  - Performance monitoring
  - Inventory
  - Workorder Scheduling and Tracking



Summary

- ALERT2 Maintenance
  - Performance Reporting
  - Time slot management
  - Field decoding tool
  - Inventory management of configuration