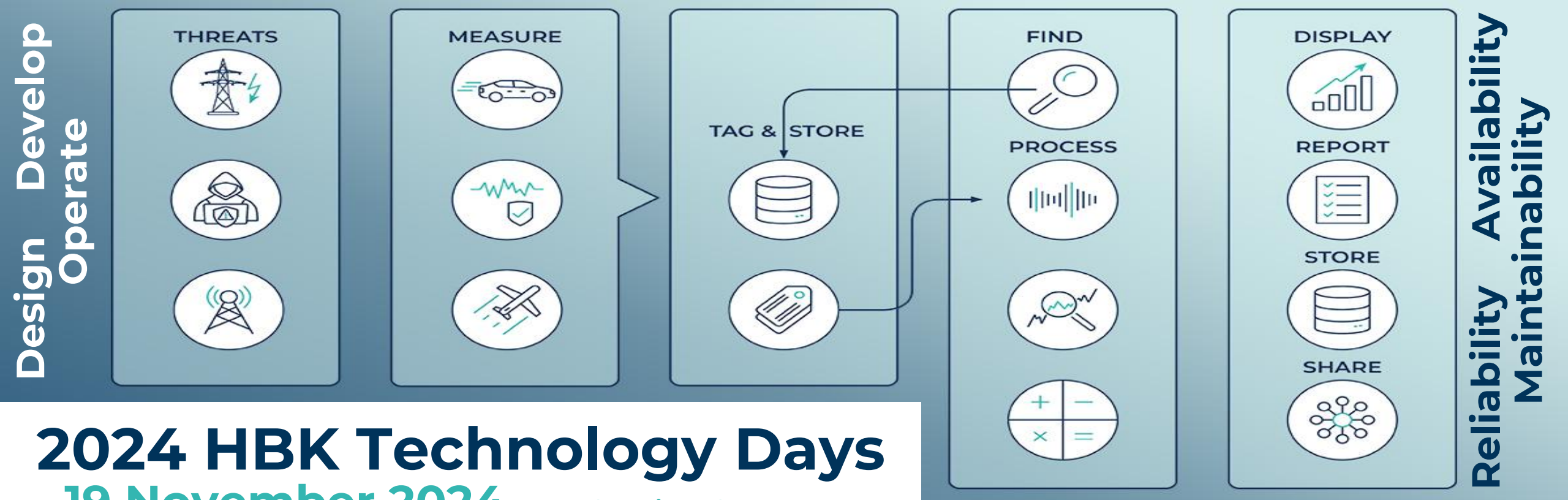




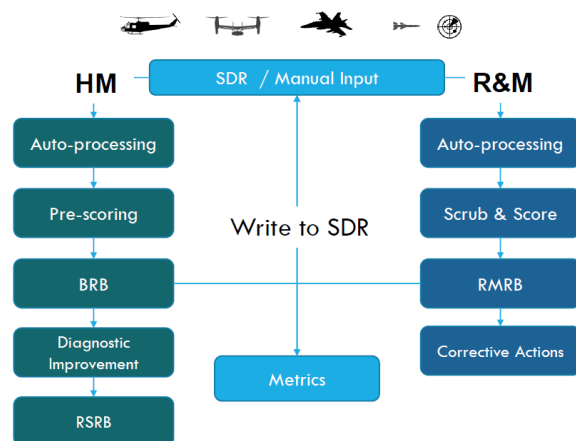
2024 HBK Technology Days

19 November 2024

Session 6:

The ...abilities – Reliability, Availability, Maintainability (RAM) for Dependability

C-FRACAS+ Process Approach



MAF - Maintenance action
SDR - Data warehouse
HM - Health Monitoring
BRB - HM Review Board
RMRB - R&M Review Board
RSRB - Ruleset Review Board

- Implementing FRACAS to improve readiness and prognostic health management at NAWCAD

Dr. Kevin Knill,
 Head of Software Solutions, HBK Engineering Solutions, HBK

Implementing FRACAS to improve readiness and prognostic health management at NAWCAD

▲ Abstract

- The Naval Air Warfare Center Aircraft Division (NAWCAD) has developed a common FRACAS (C-FRACAS+) tool to enhance operational readiness and to develop more effective prognostic health monitoring. C-FRACAS+ is being applied across most aircraft platforms, support systems and on-wing equipment at all stages of system lifecycle from early development to sustainment.
- This presentation describes the techniques used in NAWCAD to implement R&M and PHM programs and how C-FRACAS+ integral to process improvement. Particular attention is directed to how maintenance and diagnostic data are coupled to improve insights into failures and to drive better diagnostics.
- Lessons learned during implementation and operation are covered to identify successes, ongoing challenges and future developments.

Implementing FRACAS to improve readiness and prognostic health management at NAWCAD

- ▲ About the presenter, Dr. Kevin Knill,
Head of Software Solutions, HBK Engineering Solutions, HBK
 - Dr Knill has a PhD in Mechanical Engineering for Delft University. With over 8 years of experience in chemical processing and power generation and 35 years of experience in engineering software, he has designed and developed a wide range of industrial solutions.
 - He spent his early years studying how to turn coal into oil and industrial burner pollutant emission reduction. What followed was a switch to software. He developed advanced computational fluid dynamic models and lead the CFX (now Ansys) customer-directed development program.
 - When CFX joined with nCode in 2000, he moved to nCode and directed GlyphWorks, DesignLife and Automation development. After a few years away in the Insurance industry, he rejoined what was now HBK and is working in the Solutions team. He is currently developing and implementing fleet maintenance and prognostic health monitoring solutions in large scale installations.

HBK – Hottinger Brüel & Kjær

IMPLEMENTING FRACAS TO IMPROVE

READINESS AND PROGNOSTIC HEALTH MANAGEMENT AT NAWCAD

KEVIN KNILL

HBK ESO TEAM

Naval Air Warfare Center Aircraft Division



Fixed Wing



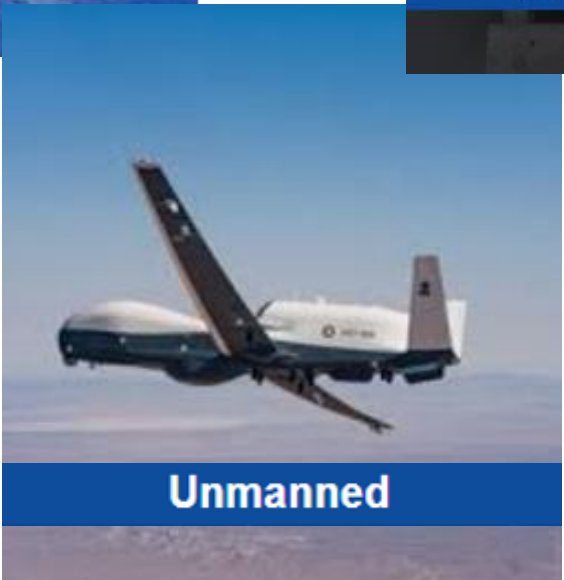
Weapons



Aviation Systems



Rotorcraft



Unmanned

NAWCAD'S C-FRACAS+ Requirements

▲ C- FRACAS+: Common Failure Reporting and Corrective Action System Plus

- Improve overall mission reliability and readiness
- Correlate R&M to PHM data

▲ Provides for:

- Root cause identification
- Improvement degrader identification and fault resolution

▲ Full lifecycle management

- Platform agnostic across Naval Aviation Enterprise (NAE)
- Entire lifecycle (Development, Test, Operations and Sustainment)

▲ Configured COTS Software

- System built on **HBK XFRACAS** platform

NAWCAD: C-FRACAS+

System Details

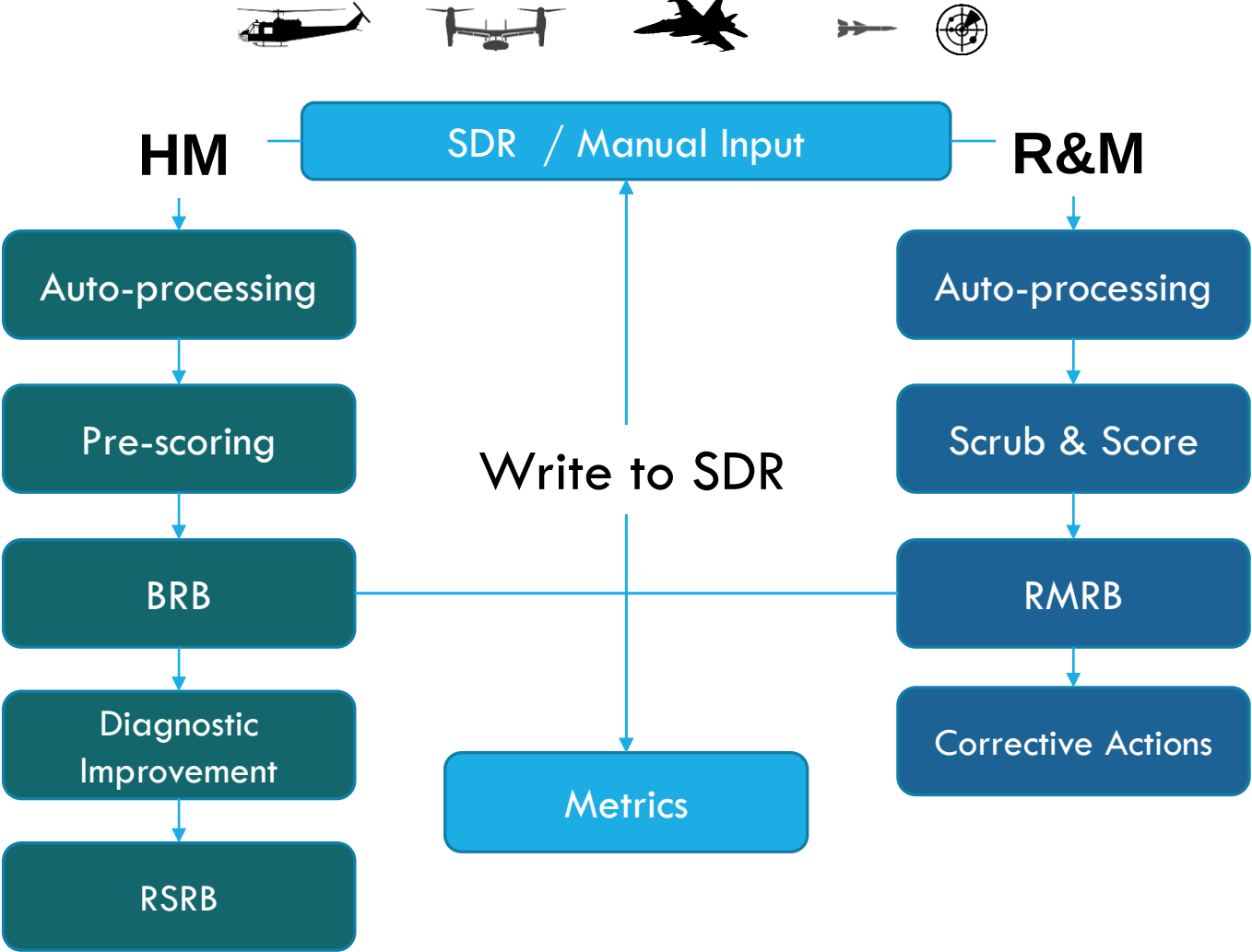
- 20 platforms
- 4M maintenance events / yr
- 1M flights / yr

Benefits of larger RCB process

- 20% increase in operational readiness
- Elimination of processing backlogs
- Automate 90% of diagnostic analysis

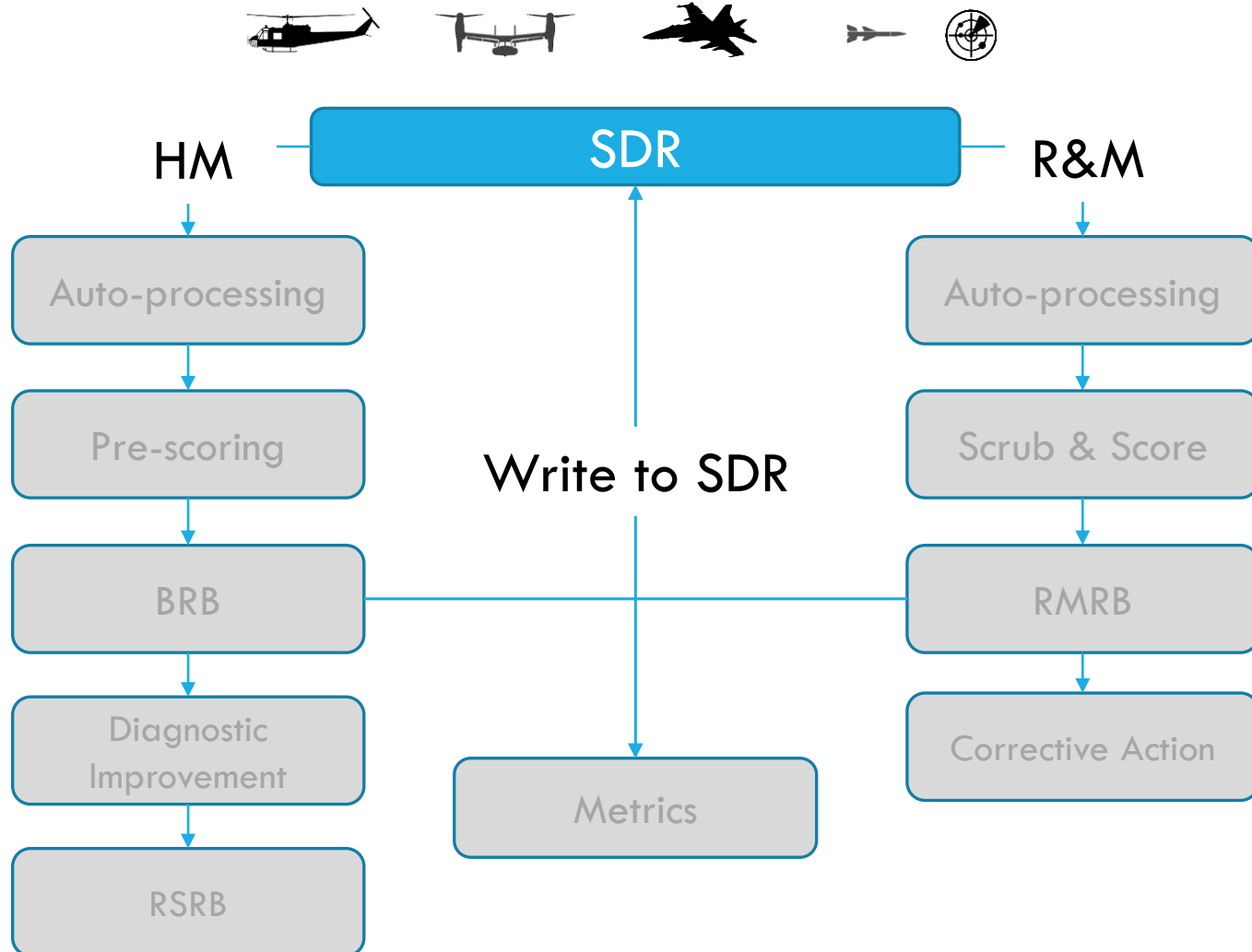


C-FRACAS+ Process Approach



- MAF** - Maintenance action
- SDR**- Data warehouse
- HM** - Health Monitoring
- BRB** - HM Review Board
- RMRB** - R&M Review Board
- RSRB** - Ruleset Review Board

Centralized Data Repository



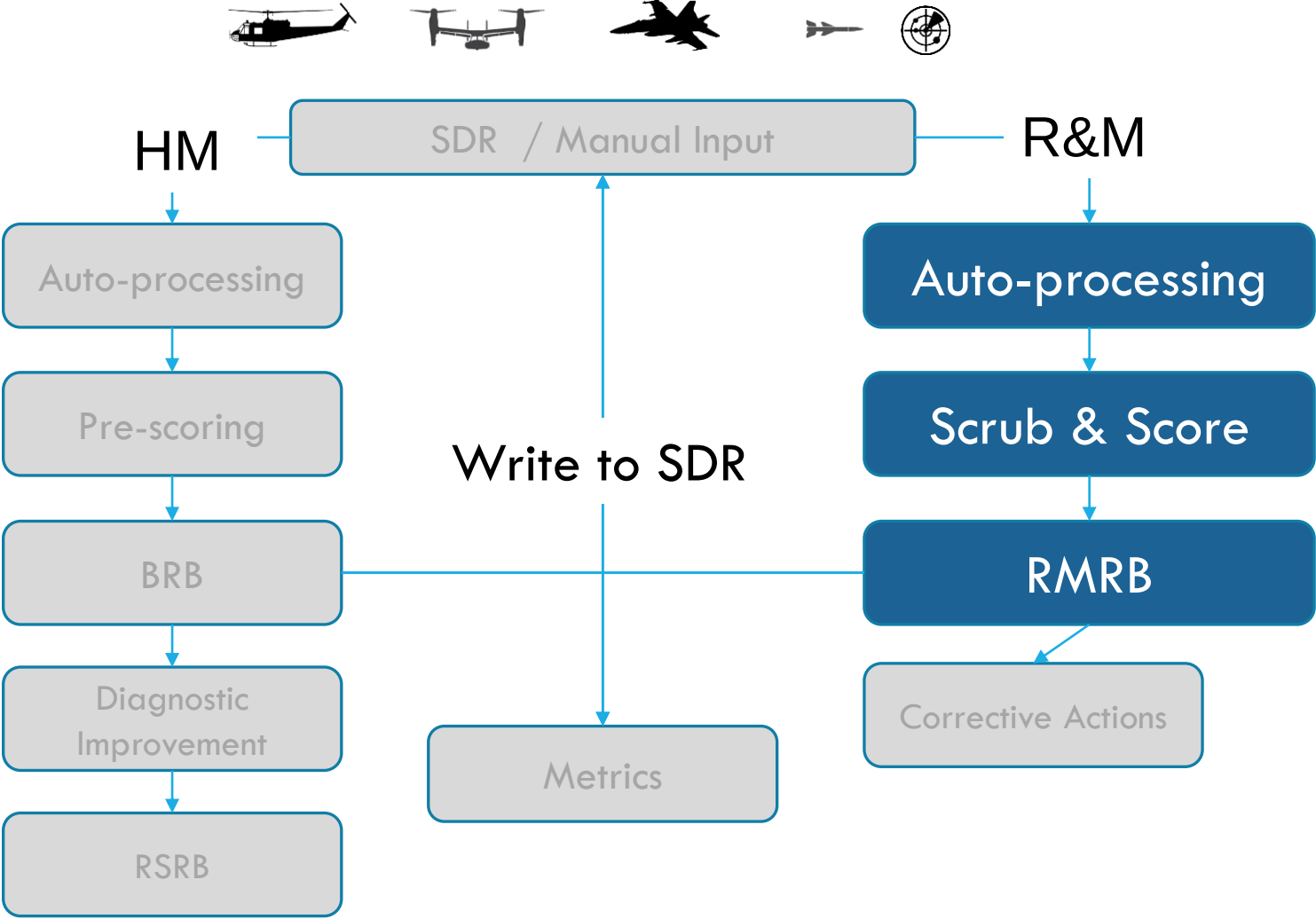
Data warehouse

- Centralizes data extraction
- Flight diagnostics
- CMMS data
- Configurable extraction

Ensures up-to-date data inputs

Share corrected data

R&M Analysis



Review and validation of maintenance data a key activity for most platforms

Maintenance and Flight Data

Maintenance

Aircraft
Part
Discrepancy
Corrective Action
Reason
Action Taken
Malfunction
When discovered
Removed P/N, S/N
Installed P/N, S/N
Mission impact
Maintenance time
Maintenance effort
Score

Flight

Aircraft
Date
Flight hours

Maintenance data can be incomplete

*C-FRACAS+ provides a way to persist
approved data corrections*

*All MAFs scored for relevancy:
(reliability, maintainability, not relevant)*

C-FRACAS+ Auto-Processing

Scoring

- Explicit algorithm based on maintenance codes, written info
- 90-95% accuracy for R&M relevancy

Parent / Child Relationships

- Relate maintenance actions to family representing a single issue
- Only score parent as relevant failure
- Automatically rollup maintenance time and effort

Flight association

- Identify the flight related to maintenance

Scrub and Score

Isolate failure and accurately record action

- Focus on reliability relevant maintenance
- Identify failure modes

C-FRACAS+ persists data corrections

- Classification codes, mission impact
- Elapsed time and effort
- R&M relevancy
- Failure mode

RMRB

Official maintenance scoring review

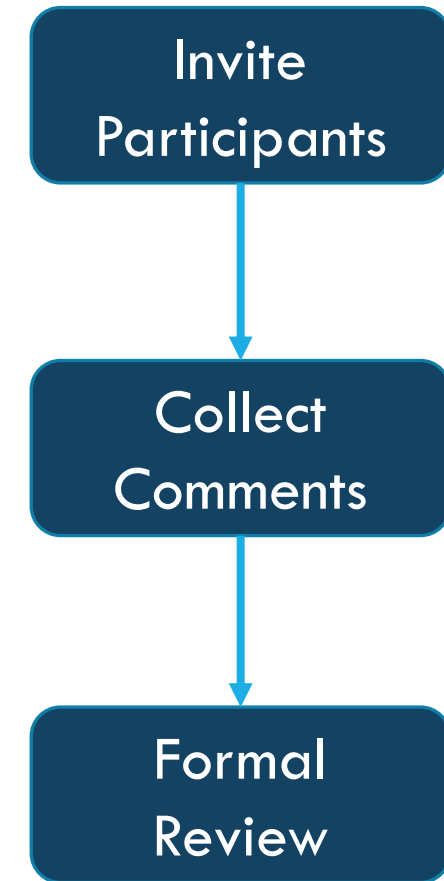
- All new programs and some sustainment programs

Finalize maintenance details

- Classification
- Scoring
- Failure analysis

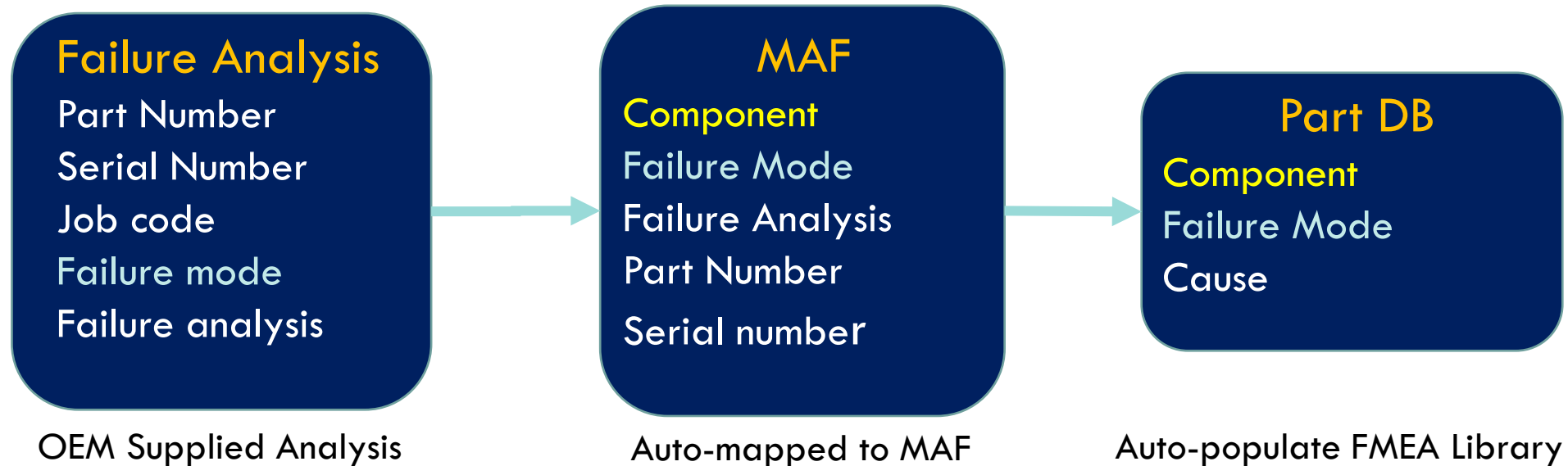
Track component degraders

- Corrective Action Plans (CAPs)

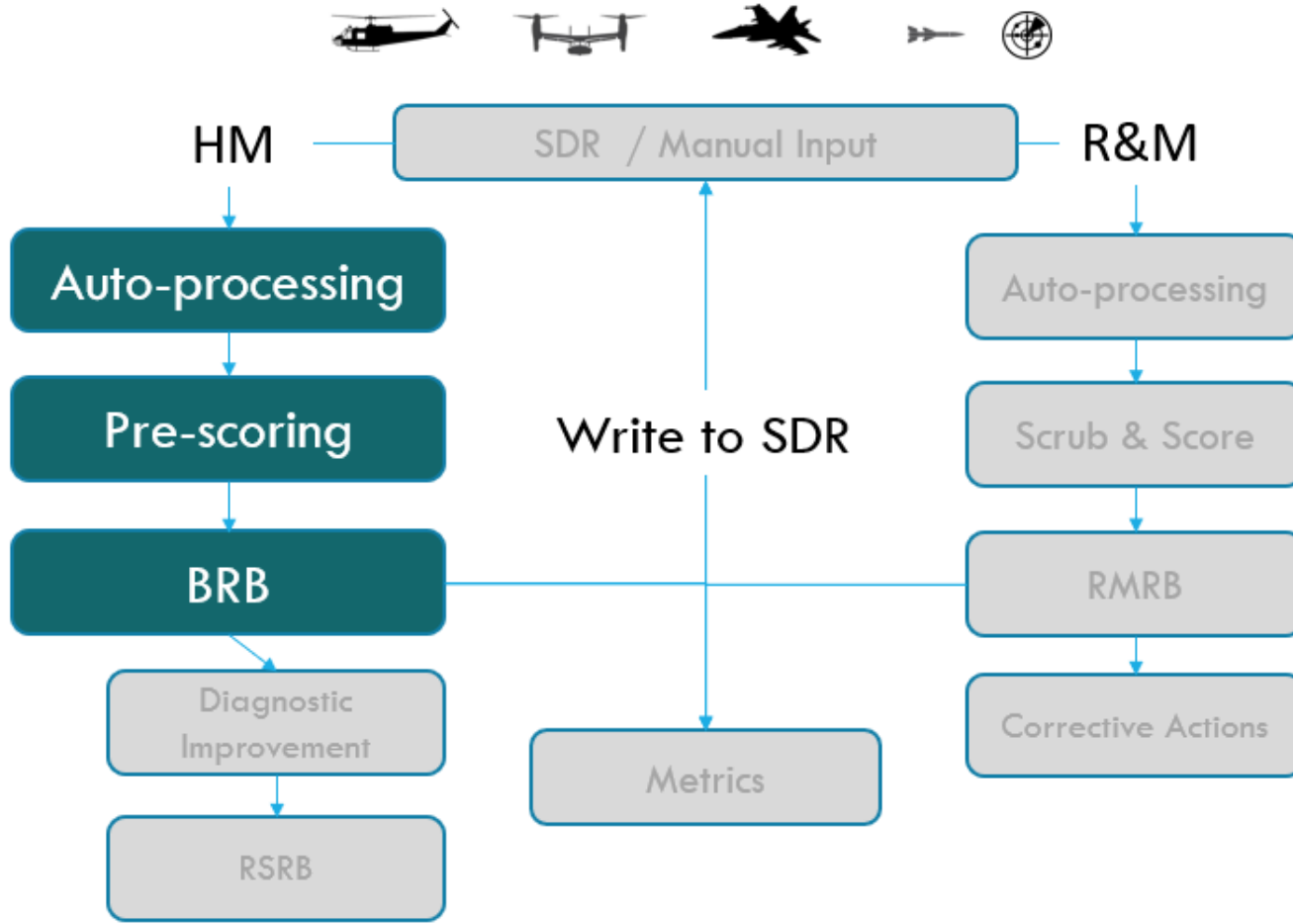


Vendor Failure Analysis

- ▲ Parts sent back to OEM for failure analysis
- ▲ Analysis aligned to maintenance action
- ▲ Failure mode added to part database



HM Analysis



Flights can contain 1000's of alerts

Goal is to identify faults of interest

Alerts scored by ability to detect and isolate faults and the subsequent action to be taken

FID code used to score each alert

Example FID Codes

Type	Code	
Correct Detect And Isolation	A113	Isolated to 3 parts
Correct Detect / Manual Isolation	A130	Requires maintainer to isolate
Servicing Detected	S110	Correct indication
Correct Detect / Deferred Repair	D110	Issue may reoccur
Engineering Investigation	E110	Requires in-depth analysis
False Alarm	F110	No hardware failure
Exceedance	K110	Correct indication
Prognostics Indication	P110	Part removed based on diagnostic
Rulesets	R112	No maintenance based on ruleset

C-FRACAS+ HM Pre-processing

Process each alert in every flight

Identify flight mode: start-up, preflight, inflight, postflight

Classify each alert by FID code

- Isolate to component or assembly of components
- False alarms
- Known issues
- Alerts that can be ignored
- Identifies what action should have been taken

Processing Rules Engine

Rules engine used to create the algorithm used to assign FID codes

Set the FID code based on

- Subsystem and alert code
- Flight mode
- Bit information
- Firmware version number
- Cascading alerts
- Recurring alerts

Set instructions/notes to Analyst to score manually

Identify expected component fault source

Associating Alerts to Maintenance

Part

Component
Failure Mode
Cause

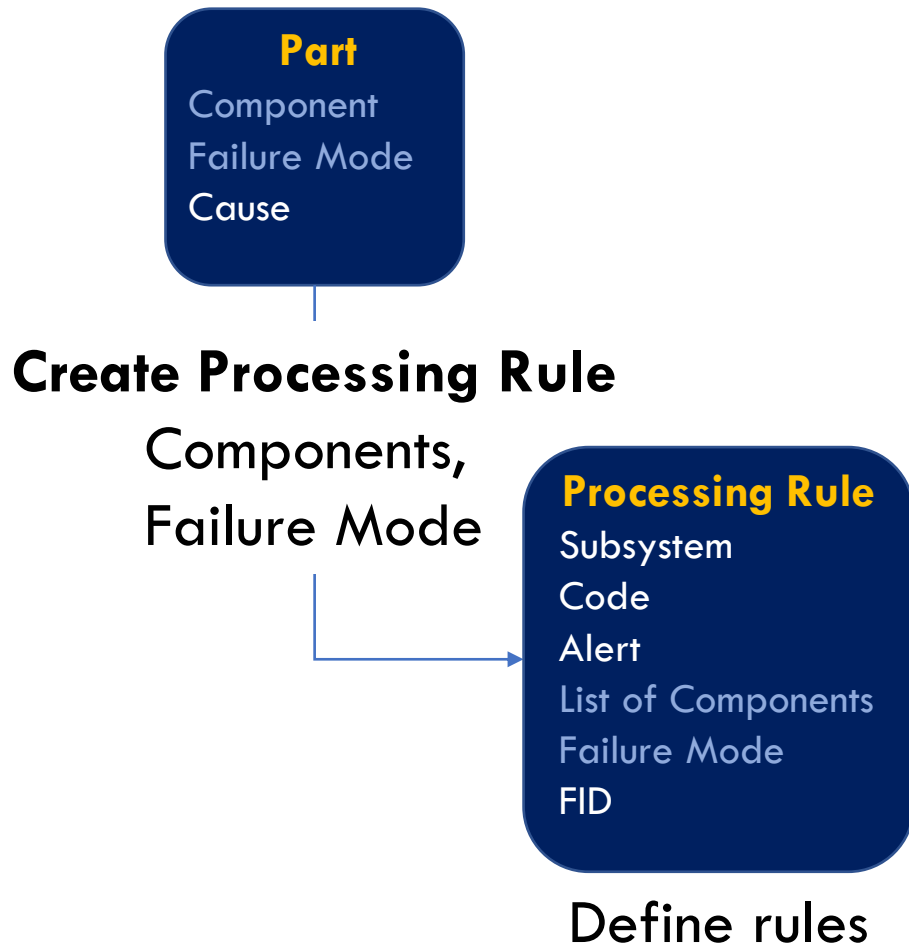
A goal of C-FRACAS+ is to relate alerts to maintenance

Understand where alerts identify issues by measuring maintenance performed

Assess whether maintenance is effective by tracking subsequent alerts

Correlating alerts to maintenance drives improvement

Associating Alerts to Maintenance



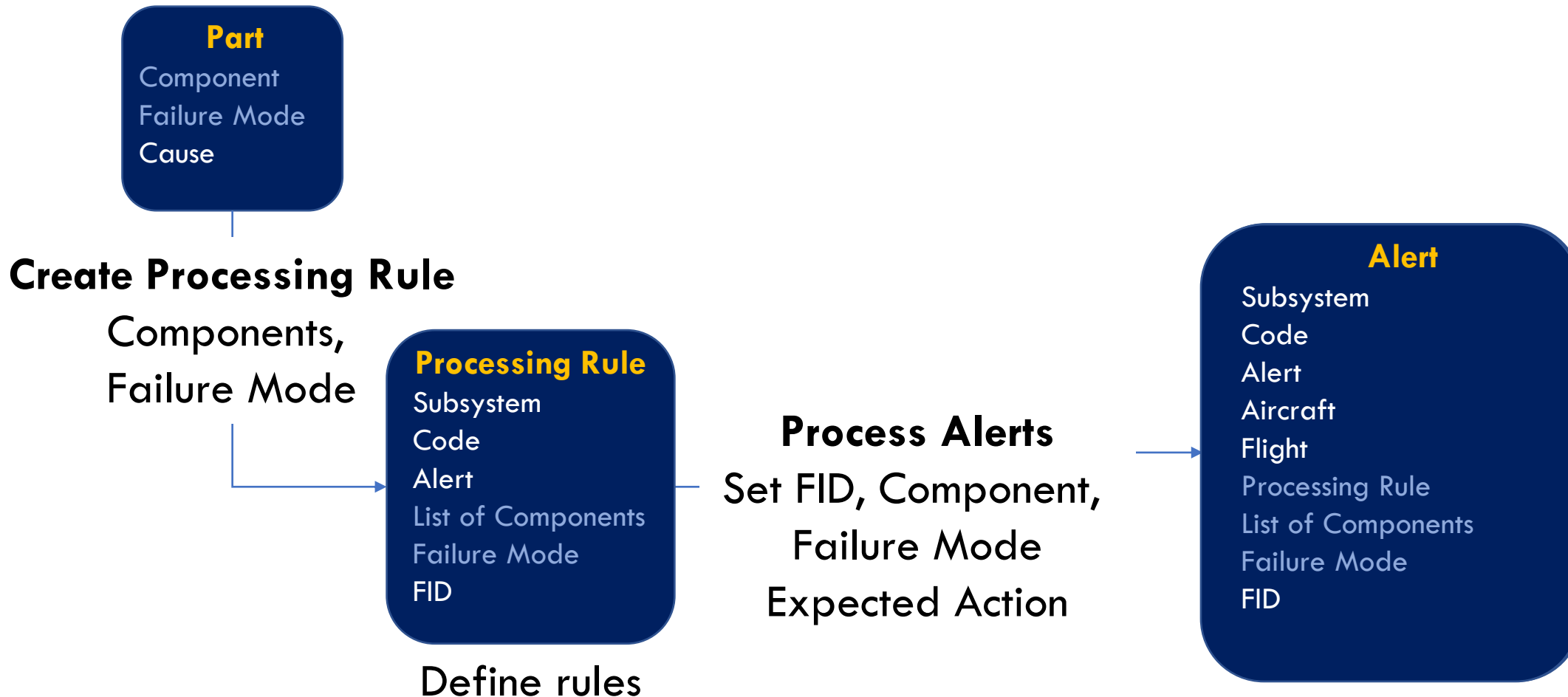
Create processing rules to establish alerts that point to part issue

Use actual data to establish the efficacy of those alerts

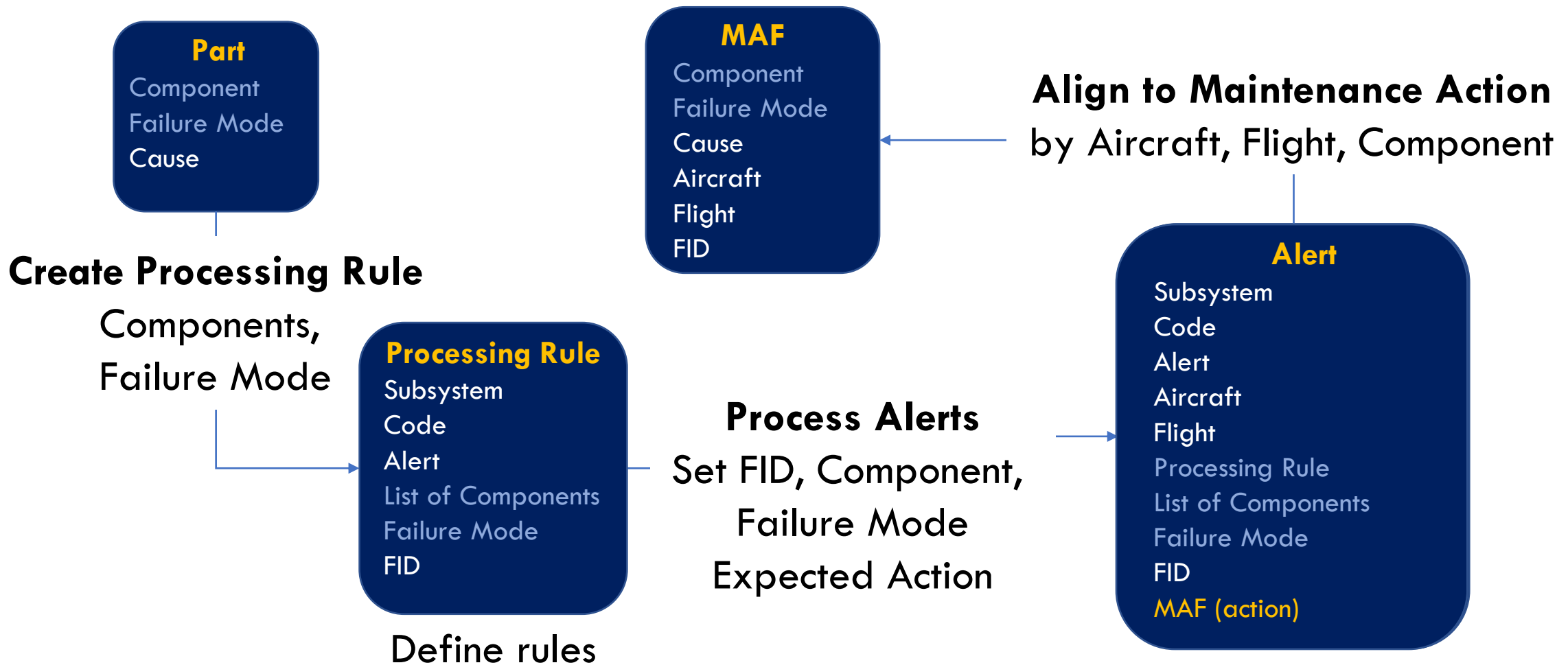
Correct rules based on results

Drive changes to maintenance procedures and diagnostic algorithms

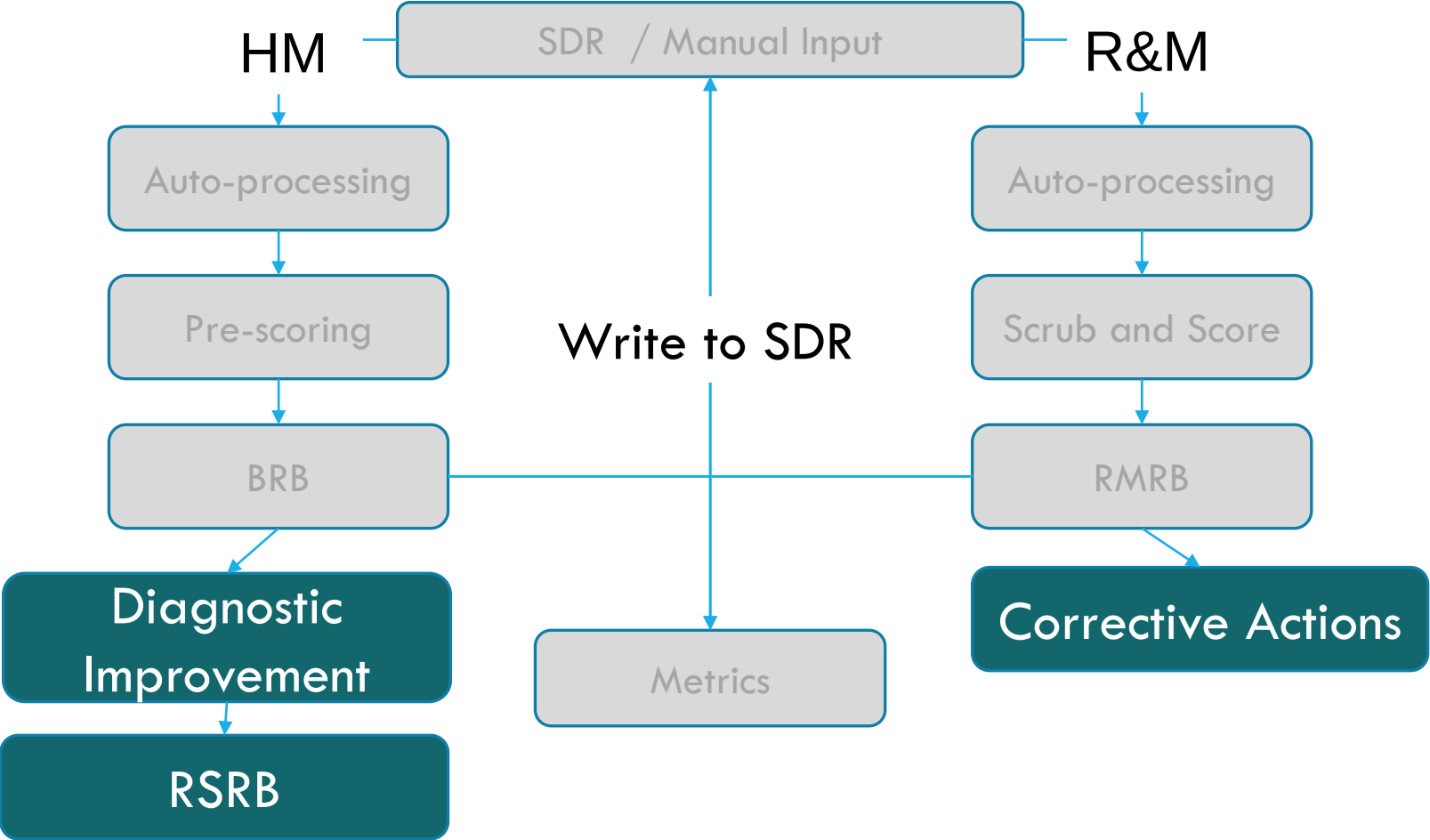
Associating Alerts to Maintenance



Associating Alerts to Maintenance



Corrective Actions and Rulesets



C-FRACAS+ manages the process of improving component performance and alert effectiveness

Corrective Actions

Corrective Action Planning (CAP) built into C-FRACAS+

Manage corrective actions using 8D process

Used in:

- R&M component analysis
- HM alert improvements
- Ruleset creation and review

The screenshot displays the C-FRACAS+ web interface for a Corrective Action Planning (CAP) entry. The top navigation bar includes links for Home, System, Admin, and Options. The main header shows the user 'KEVIN KNILL' and the aircraft 'HT11 | MFD/Map Fail'. The CAP Summary section provides key details: Closure Requested, Owner (WEGSCHEID, TEARESA), Priority (High), Last Occurrence (09/08/2020), Last Updated (10/14/2020), Creator (WEGSCHEID, TEARESA), Process Status (Monitor Corrective Action Effectiveness), Expected Closure Date (10/28/2020), Created Date (09/28/2020), First Occurrence (09/08/2020), and Last Updated By (WEGSCHEID, TEARESA). Below the summary are expandable sections for Contact & CAP Information, CAP Description, Implement and Verify Short Term Fix Actions, Identify and Verify Root Cause, Solution Analyses Actions, Corrective Actions Incorporation, and Monitor Corrective Action Effectiveness. The bottom of the form includes a 'Set Close Status' dropdown, a 'Close Date' field set to 'Oct', and a 'Time' field set to 'Local Time'.

Rulesets

Rulesets define actions taken as a result of an alert

- Maintenance plan and task sequencing
- Part replacement

In some cases, Rulesets can be integrated into control systems

- UAS ground stations

C-FRACAS+ manages ruleset creation and approval

Ruleset Board (RSRB)

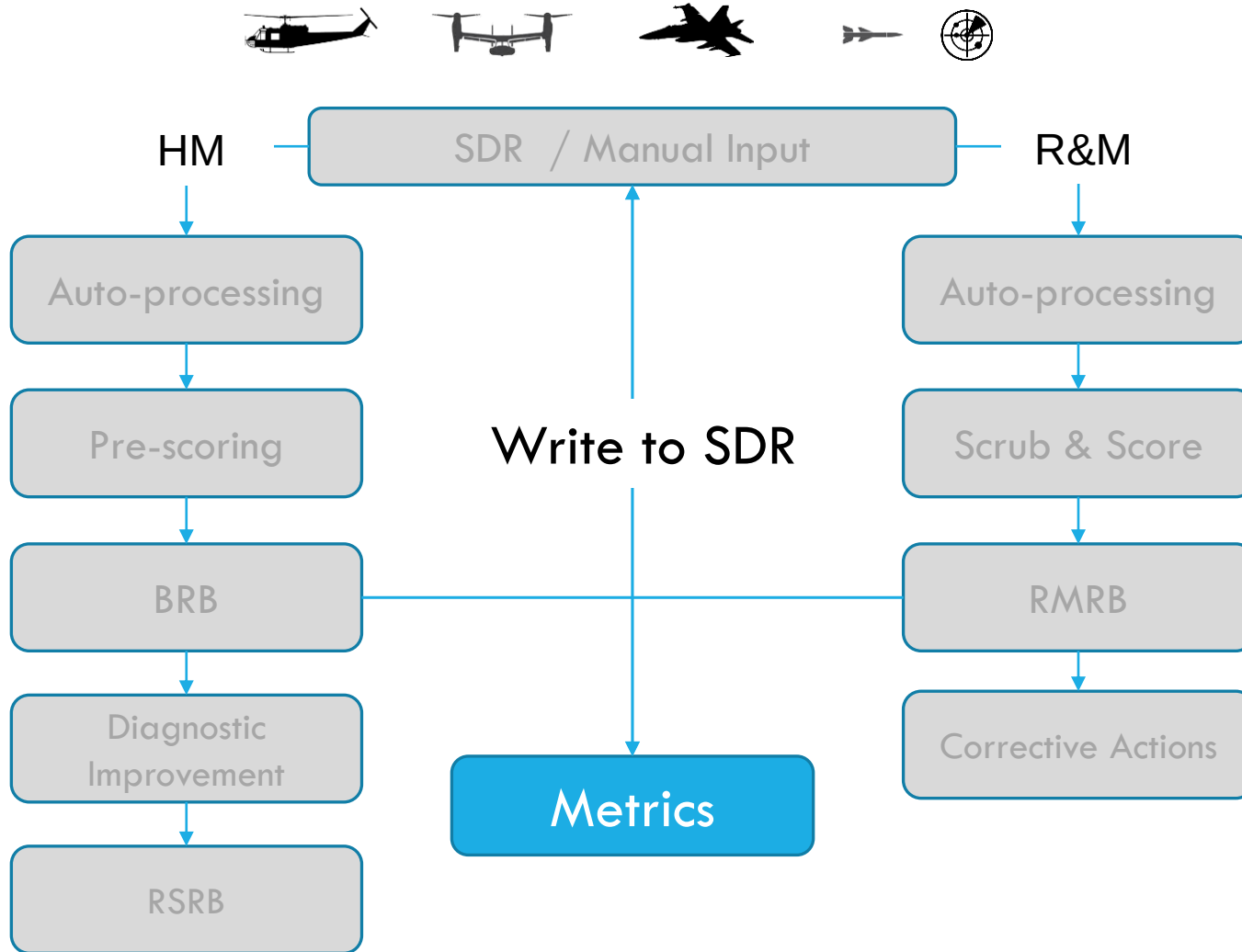
Assess the findings of alert/maintenance interaction

Review and update maintenance plans

Manage ruleset review and approval

Publish rulesets and incorporate into Ground Station control systems

Metrics



Metrics are the analytical engine of C-FRACAS+

Metrics help identify underlying issues, high drivers and performance trends

Metrics correlate alert/maintenance actions and measure fix effectiveness

Metric Runner

C-FRACAS+ includes a utility to run prescribed metric calculations

Utilizes a library of metrics to run against selected data

- Parametric inputs
- Processing algorithm
- Results presentation

Metrics available

- Standard metrics
- New and PMA specific analysis

Standard Metrics

MFHBx – 15 different standard metrics. For example:

- Failures, operational mission failures
- Scheduled and unscheduled maintenance

RAM Metrics

- Reliability, maintainability, operational availability

HM metrics (per flight hour):

- Fault detection / isolation rates
- False alarm rate

Specific Metrics

General

- Fix effectiveness
- Time on wing
- Time to failure
- Failure / suspension extraction

Part based

- High drivers
- Part utilization
- Part performance

Flight

- Flight deep dive

Processing rules

- Scoring simulator

Adhoc - Select Metric

Metric Type*
General ▼

Metric*
Select a metric... ▼

Q |

- aircraft_metric2
- aircraft_metric2_LD
- corrective_action_effectiveness_metric
- failure_suspension_extraction2
- time_on_wing_metric
- time_on_wing_SN_metric
- time_to_failure_metric

Examples

PMA-276
H-1 Helicopter



PMA-262
Triton Unmanned Aerial System



PMA-276 H-1 Helicopter

Program in sustainment

Currently focused on R&M analysis in C-FRACAS+

- 400k MAFs/year
- 130k flights/year



H-1 PMA Feedback

Data ingestion

- Eliminated 2-3 days a week of manual data loading
- Allows focus on analysis and identification of emerging items

Scoring & Review

- Automated script quickly identifies degraders
- Immediate feedback on potential degraders and emerging items
- RMRB data prep reduced from full time job to one week/month
- RMRB Chair can review maintenance actions daily

PMA-262 MQ-4C Triton

In Operation Evaluation with ongoing system and capability upgrades

- Unmanned aerial system
- Aircraft and ground station
- Focus on overall mission reliability



Ongoing Configuration Usage

R&M

- Degradation identification
- Using HM data to estimate remaining useful life
- Weibull analyses, reliability growth

HM

- Diagnostics performance and improvement (100x)
- Utilizing processing rules to score alerts (> 500 rules)
- Developing rulesets to use in fleet planeside maintenance

Expected Benefits

Driving degrader identification

- Tech refresh opportunities
- Diagnostics and BIT SW improvement opportunities

Ruleset development and verification

- Driving maintenance actions
- Uncovering engineering investigation opportunities

Enhanced Reliability Control Board corrective action / mitigation

- Speed to the fleet with improved capabilities and products
- Cross Platform information sharing

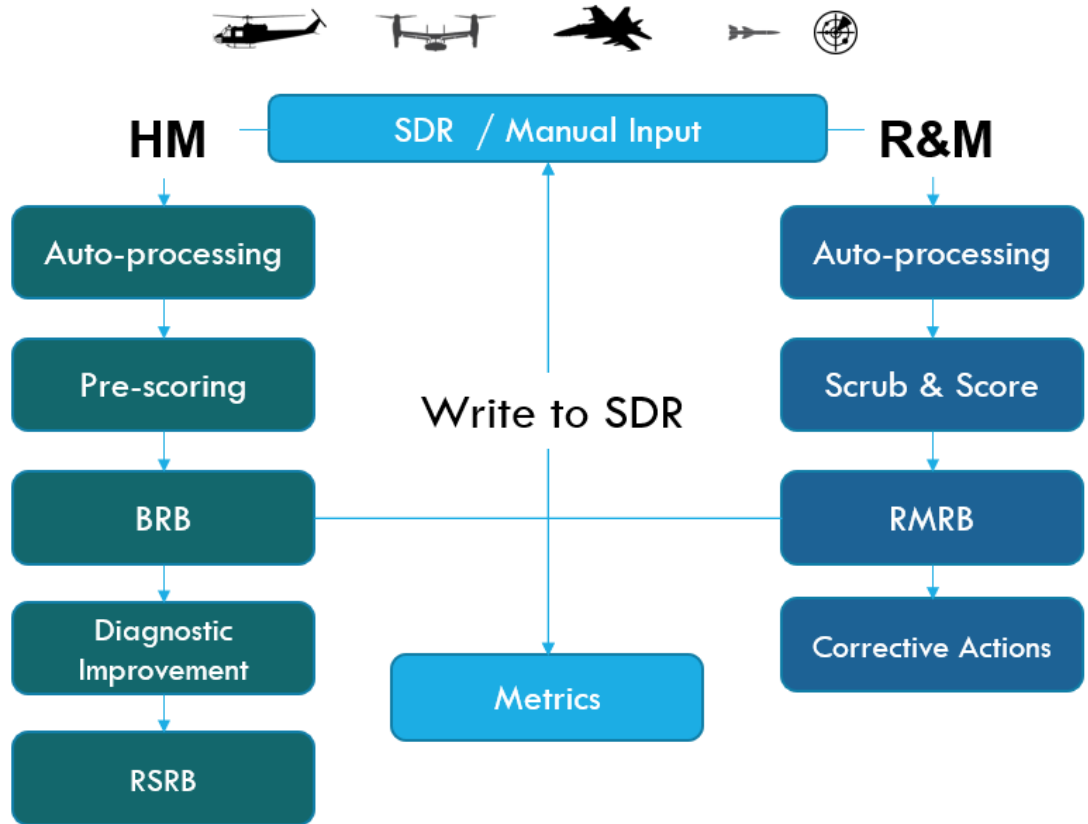
Summary

NAWCAD deployment

- Implemented on 20 platforms to date

NAWCAD standardizing on C-FRACAS+

- R&M and PHM tool of choice
- Applying common analysis processes
- Sharing best available data

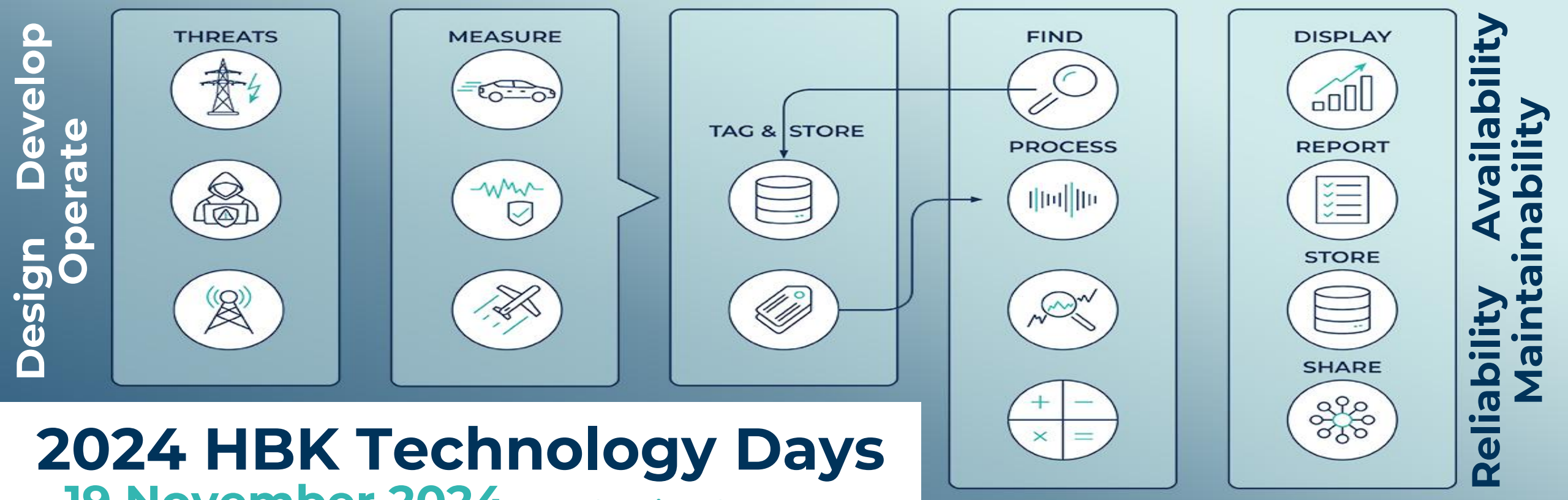


Future Work

Continue implementation across remaining NAWCAD platforms

Expanding to enterprise-wide Lifecycle Failure Mode Management

- **Rulesets:** better prescribe maintenance based on alerts
- **Reliability:** better identify failure modes for replaced components
- **Monitoring:** improve alert efficacy to detect and isolate failures
- **Design:** deliver failure / HM relationships to improve product



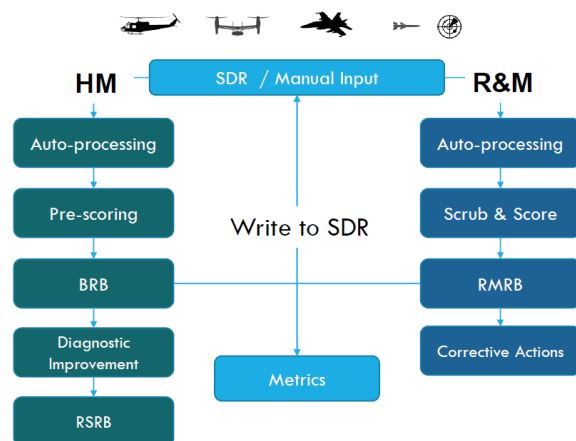
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