ROOT CAUSE ANALYSIS AND THE BOEING PROBLEM SOLVING MODEL

Utilizing the Apollo Root Cause Analysis methodology and RealityCharting® Software in Boeing's 5-Step Root Cause Corrective Action Model for Effective Problem Solving

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OVERVIEW

This white paper describes performing Root Cause Analysis (RCA) utilizing the Boeing Problem Solving Model-Root Cause Corrective Action (BPSM-RCCA). It details one Boeing Technical Principal's use of the Apollo Root Cause Analysis methodology and RealityCharting® software during a problem-solving project.

The Apollo Root Cause Analysis methodology was created by Apollonian Publications. ARMS Reliability is Licensed to use and distribute Apollo Root Cause Analysis methodology materials. RealityCharting® and RC Pro™ are the software tools that support the Apollo Root Cause Analysis methodology.

ABOUT JENNIFER MACKAY

Jennifer is the only Root Cause Analysis Technical Principal at The Boeing Company. She provides RCA consultations, investigations, and holds workshops across the Boeing enterprise, addressing some of Boeing's most complex and longest running production and process issues.

She joined the Boeing Company as a manufacturing engineering planner in 1991, and in 2007 took on the role of RCA specialist. In this role, she conducts full Root Cause Analysis and solution implementation, consults on Root Cause Analyses, and trains other employees in RCA. She frequently holds internal training sessions and has taught over 900 Boeing employees the RCA skillset to date.

To understand how crucial problem-solving is at Boeing it helps to understand the scale of the company. Boeing is the world's largest aerospace company and America's biggest manufacturing exporter. The Commercial Airplanes portion of the business employs more than 83,000 people worldwide, has more than 10,000 Boeing commercial jetliners currently in service and a record 5,500 more on order.

The production facility where she works in Everett, WA is the largest building, by volume, in the world according to the Guinness Book of World Records. There is a lot of

Figure 1: Jennifer MacKay, Root Cause Analysis Technical Principal, The Boeing Company

room, literally, for problem-solving and process improvement especially when you consider that in a single 777 aircraft, there are 3 million parts provided by 900 suppliers from 17 countries around the world.

BOEING PROBLEM SOLVING MODEL
AN OVERVIEW

The Boeing Problem Solving Model provides a structured approach to continuous improvement. It can be used to solve problems or capture opportunities of any size or scope. This model is the standard problem solving method for The Boeing Company.

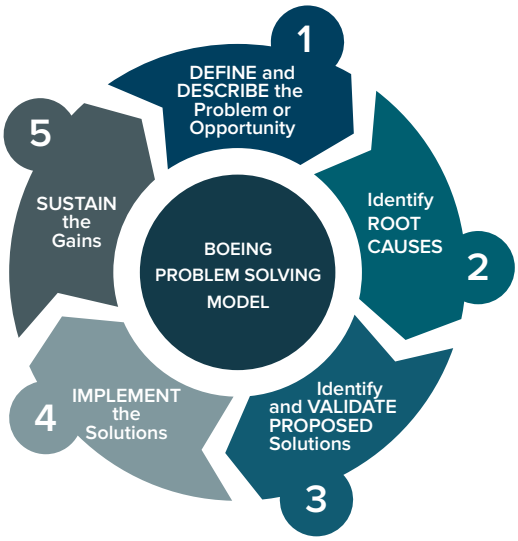

FIGURE 2: THE 5-STEP BOEING PROBLEM SOLVING MODEL

1 DEFINE & DESCRIBE THE PROBLEM OR OPPORTUNITY

RECOMMENDED TOOL:

The Problem Definition Template

This tool provides a method for developing a clear, concise statement describing the problem.

Actions to take:

- Define the current situation, ideal situation, and the gap between
- Define the scope and boundaries
- Break down the problem or opportunity
- Walk the process
- Identify existing processes/ standards
- Develop a problem statement with a clearly stated end goal
- Set measurable and challenging targets

2 IDENTIFY ROOT CAUSES

RECOMMENDED TOOL:

The 5 Whys

Start with the problem statement from Phase 1. Ask why this happened. If the answer to the initial why does not identify the root cause, continue asking "Why" until actionable root causes are identified.

Actions to take:

- Perform root cause analysis (RCA) to systematically identify all the contributors to the problem
- Validate the prioritized root cause(s) through data and walking the process
- Assure the data is valid and represents facts, not opinion

3 IDENTIFY AND VALIDATE PROPOSED SOLUTIONS

RECOMMENDED TOOL:

Improvement Actions & Expected Results

Use to describe improvement actions to be taken, the business results achieved once an action has been completed.

Actions to take:

- Identify as many potential solutions as possible that address the root cause(s) and narrow down to most practical to address the root cause(s)
- Validate preferred solution(s) through mock-up, simulation, and/or pilot as required
- Stakeholder buy-in

4 IMPLEMENT THE PROPOSED SOLUTION

RECOMMENDED TOOL:

Action Item List

Review progress on a regular basis and assure that team members are accountable to complete the items. Items may be related to deliverables or be in general support of the plan.

Actions to take:

- Capture actions, Responsibilities, and ECD's
- Ensure implementation is completed as defined
- Monitor and communicate progress to the plan with stakeholders
- Update standard / documentation and training as required

5 SUSTAIN THE GAINS

RECOMMENDED TOOL:

Problem Solving Model Checklist

Ensures the desired results are achieved, measured, and monitored after implementation. Minor adjustments to plan may occur over time to sustain the benefits.

Actions to take:

- Ensure solutions meet/ produce the expected results
- Verify the problem defined is resolved or mitigated
- Monitor results over time
- Share results with stakeholders
- Ensure the new standard is maintained

FIGURE 3: DETAILS OF THE 5-STEP BPSM, INCLUDING RECOMMENDED TOOLS

APOLLO ROOT CAUSE ANALYSIS METHODOLOGY: The BPSM does not limit users to a specific set of tools for problem solving at any stage of the process. There are many different approaches for analyzing root causes and the Apollo Root Cause Analysis methodology and RealityCharting® software work well within the Boeing process.

The Apollo Root Cause Analysis methodology provides a multi cause-and-effect way of thinking and goes far beyond the traditional root cause analysis problem solving processes. It facilitates the creation of a common reality, using input from all stakeholders to produce an evidence-based understanding of a problem. This method ensures that solutions address proven causes, not assumed causes.

REALITYCHARTING®: This software is a powerful Root Cause Analysis tool used to assist facilitators and complement the Apollo Root Cause Analysis methodology. It is user-friendly and enables individuals to accurately identify and document the root causes of a problem. RealityCharts made with RealityCharting® help users obtain a better understanding of cause-and-effect relationships and this leads to identifying effective potential solutions to prevent recurrence.

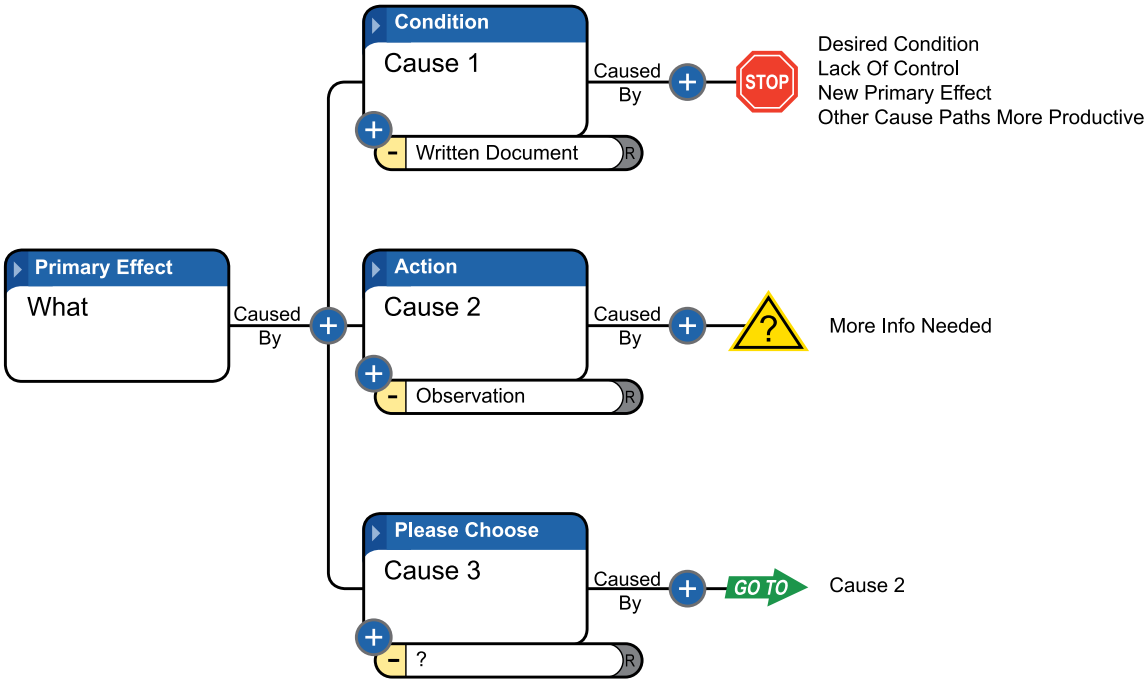

FIGURE 4: A SAMPLE REALITYCHART CREATED IN REALITYCHARTING®

STEP 1 DEFINE AND DESCRIBE THE PROBLEM OR OPPORTUNITY

The investigation phase of the BPSM process can involve:

CONTAINMENT:

Depending on the problem this could involve containing a situation so issues don't progress further. This is especially important in the production environment.

REVIEWING THE "AS-DESIGNED" CONDITION:

Review the engineering drawings, specifications, and tooling from the design team.

REVIEWING THE "AS-PLANNED" CONDITION:

Review the manufacturing engineering plans that resulted from the initial design.

OBSERVING THE "AS-BUILT" CONDITION/PROCESS:

Witness the process in real-time; take photos and/or video to reference later. Perform surveys, look at technical data from past incidents, ask witnesses what happened, and see it first-hand. Give different weights to different types of data - i.e. eyewitness recollections versus empirical data. Bring in suppliers or go visit suppliers to understand their processes.

"I was working a wing project a while back, and the lead Quality Inspector who'd been there for 10 years had seen an error occurring on the 777 wing and swore that it was happening five to seven times per wing, no more. However, I needed to validate and quantify the true quantity. We invoked process monitoring on 3 airplanes and found that this particular error was happening 94 times, per wing, on average. The Quality Inspector was shocked and was worried I would think he'd been lying to me. But I knew he wasn't. People will give you their assumptions based on what they know… but they don't know what they don't know."
– Jennifer MacKay

COMPARING THE AS-DESIGNED, AS-PLANNED, AND AS-BUILT:

Unfortunately, the designed, planned and built configuration don't always match up like they should. If it can be determined how/why things don't match up then potential solutions begin to form.

DRAFTING A CHARTER:

A charter is a simple word document that lists the problem description, deliverables, objectives, and scope/boundaries. An agreed-upon charter ensures all stakeholders are in alignment at project initiation.

"I found out how important a charter was when I didn't create it once. At the end of the investigation, after we had implemented two stellar solutions and had completed a report about how successful our RCA had been, my manager came up to me and said, 'Jennifer, that was fantastic, but it wasn't the problem I wanted you to fix.'"
– Jennifer MacKay

STEP 2 IDENTIFY ROOT CAUSES

Identifying and exploring causal relationships can involve:

CREATING A CAUSE-AND-EFFECT MAP USING APOLLO ROOT CAUSE ANALYSIS METHODOLOGY AND REALITYCHARTING® SOFTWARE:

RealityCharting® helps identify and record all of the causes of, and contributors to, a problem. Mapping out the relationships enables potential solutions to be more apparent. There are multiple approaches for creating a Realitychart:

INITIAL DRAFT

Independently create an initial Realitychart draft. Print it out and share it with Subject Matter Experts one-on-one, face-to-face.

"About a third of the time, I get to solutions that I'm confident in and I don't feel it's necessary to pull together a team."
– Jennifer MacKay

GATHER A SMALL TEAM

Share the initial Realitychart draft with a small team of Subject Matter Experts in a group setting. Go through the cause-boxes one-by-one and expand the map with the input received from the team.

HOLD A WORKSHOP

There's a spark that happens when you gather a team in a room to focus on a problem; the brainstorming and creativity that results from the synergy is irreplaceable. Convene a workshop for two reasons:

1. There isn't confidence that the individually determined solutions identified in the Realitychart draft will truly fix the problem.

2. The independently proposed solutions might be controversial, or the people who will need to be involved in implementing the solutions aren't currently on-board and their support is needed.

Resources are usually limited and people are busy so be judicious about planning workshops. Schedule two four-hour sessions with a couple days in between, and then however many one to two-hour follow-up sessions are necessary in the following weeks.

FIGURE 5: RCA WORKSHOP

ADDITIONAL INVESTIGATING:

Creating the RealityChart® will often uncover questions or areas where more information is needed. Additional investigations may be required to provide evidence to validate a particular cause-path or potential solution. Investigation often includes a historical "deep dive" to quantify "heavy hitters" or frequent contributors to the problem, ex: does the problem only occur on a left hand wing and not the right hand? Does it occur when performed on one shift versus another?

UTILIZING CROSS-FUNCTIONAL EFFORT:

Whether the investigation involves talking to individuals one-on-one or pulling together a workshop, there are certain core team members whose involvement should be considered. These can include:

- Manufacturing Engineering
- Process Engineering
- Quality Assurance Investigation
- Manufacturing Lead Mechanic
- Tooling Engineering
- Stress Engineering
- Information Technology
- Supplier Engineering
- Supplier Manufacturing
- Supplier Tooling Engineering

It is imperative to get these important groups involved at the earliest stages of the project so there is a common understanding of the problem and buy-in for Step Three – Solution Implementation. Additionally, consider anyone else who will need to be involved with implementing the solutions: customers, design engineers, researchers, facilities, management, etc.

STEP 3 IDENTIFY AND VALIDATE PROPOSED SOLUTIONS

At this step the RealityCharting® software is a very useful tool to visually depict how potential solutions can directly support problem resolution. Realitycharts can be color-coded to show potential solutions which correspond to each cause-path.

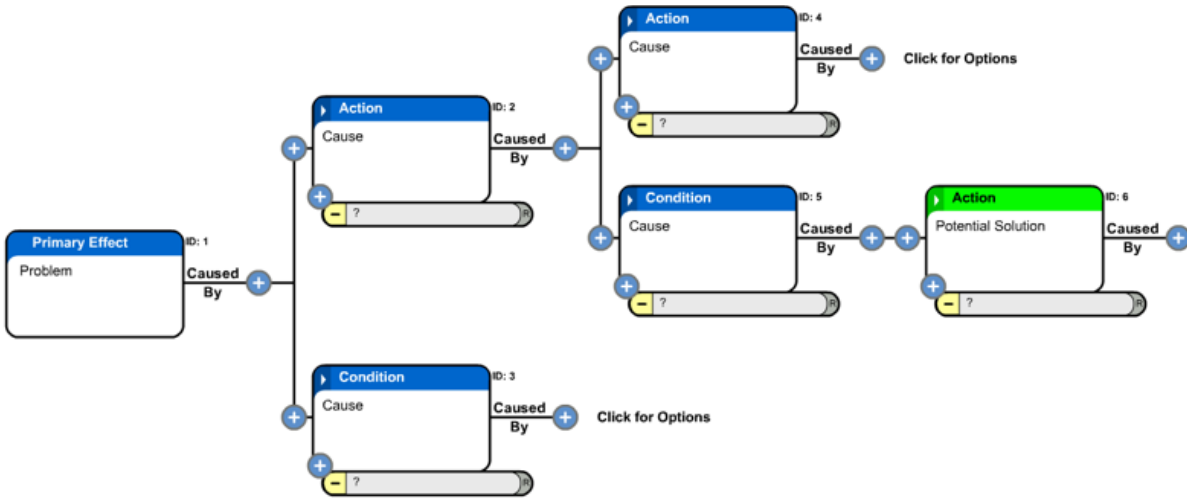

FIGURE 6: COLOR-CODED REALITYCHART

Technical experts are crucial when creating a Realitychart because they ensure all potential solutions are considered. Technical experts could include individuals such as:

Internal Subject Matter Experts:
Individuals with extensive experience in their fields.

Internal Research and Development:
Departments designated to identifying cutting-edge technologies and process improvements.

External Resources:
Other industries are usually open to building relationships and sharing information. Pursuing knowledge-transfers with outside companies can be very beneficial to both parties involved.

"In one instance, Boeing wanted to improve exterior paint quality on the wings and decided we should pursue outside expertise. As a company we are really good at continually improving the way we do what we do. But we are not always quick to recognize when something is being done better elsewhere. So, I took our team on tours of the Ford and BMW paint facilities and spoke with their paint engineering experts to see what advancements they had made in both the robotic and manual paint processes, and defect detection."
– Jennifer MacKay

DOWN-SELECTING POTENTIAL SOLUTIONS:

Often times there is no single solution that completely eliminates a problem, therefore, implementing a set of solutions can greatly reduce the probability of recurrence. Depending on the size of the project it can be easy to determine which solution(s) to implement, but if a problem is large and complex it can be difficult to proceed with confidence. However, several tools are available for down-selecting solutions such as performing an impact and changeability review and a return on investment (ROI) analysis.

Impact and Changeability Review:
Before selecting a solution consider both the impact it will have on the problem and the difficulty of implementation. Performing an impact and changeability review involves assigning a weighted number value to each potential solution which enables mathematical prioritization. The criteria can be adapted to any specific problem.

"In one RCA investigation, we identified 181 potential solutions so we had to prioritize the solutions by questioning each one."
– Jennifer MacKay

Return on Investment:
It can be value-added to determine the ROI for solution implementation; this will often times determine whether or not leadership will support a solution. Assign a dollar value to everything (flow time reduction, reducing safety risks, freeing-up floor space, eliminating heavy machinery operations, etc). Prepare ROI figures to show the cost/benefit information; determine when a potential solution will pay itself off and how much cost will be avoided in the future.

"I take my ROI down to the specific airplane level, for example: if we implement these engineering, tooling, and process changes it will cost us XX amount, the savings/benefits are XX, and we will see our return on investment on Airplane Line Number XXXX."
– Jennifer MacKay

Impact Criteria	Changeability Criteria
Degree to which the solution helps reduce the problem	Cost to implement
Degree to which the solution solves the problem(s) vs temporarily fixes it	Amount of time required to implement
Degree to which solution results in unintended (negative) consequences	Level of acceptance by factory and maintenance personnel
When rating "IMPACT" 1 = little impact 2 = some impact 3 = considerable impact	When rating "CHANGEABILITY" 1 = difficult to achieve 2 = moderate effort to achieve 3 = little or no effort to achieve

FIGURE 7: IMPACT AND CHANGEABILITY CRITERIA

Effort/Impact Analysis: Template #1

Solution Impact	(Low) Implementaion Effort (High)
(High)	Highly Effective Solutions Solution ideas placed in this quadrant (low effort, high impact) should be the focus of a team's energy since they are suspected to result in the best return investment
	Difficult-Implementation, High Value Added Solution Solution ideas placed in this quadrant (high effort, high impact) often require significant additional analysis to determine whether or not they should be implemented
(Low)	Easy-implementation, Low Value Added Solutions Solution ideas placed in this quadrant (low effort, low impact) may require additional analysis to determine whether or not they should be implemented, but teams should not fall into the trap of analysis paralysis
	Ineffective Solutions Solution ideas placed in this quadrant (high effort, low impact) should be set aside, and only reassessed if solutions in other quadrants prove to be unviable

FIGURE 8: EFFORT/IMPACT ANALYSIS TABLE

STEP 4 IMPLEMENT THE SOLUTIONS

Implementing solutions can be the most difficult step in the process, especially when solutions involve complex designs. Most solutions require effort from multiple groups, both inside and outside the company, who have different priorities and timelines. Additionally, people are frequently changing job roles in large companies; working with ever-changing points of contact can impact implementation.

Implementation effort and cost can vary wildly depending on the complexity of the problem. Don't ignore the simple, efficient, inexpensive solutions just because they aren't as exciting as the complex, revolutionary, high-tech solutions. Economical solutions can be impactful so don't lose sight of the purpose of the project: solving the problem.

VIEWS OF SUCCESS:

Things often take longer than expected, especially when other groups are involved. Progress can be out of your hands but even if things take years to fix, they're still fixed. Alternatively, a complete fix for a problem might not be feasible but improving the situation is still beneficial.

"For example, an RCA regarding a wing panel issue identified an engineering drawing change as one of the solutions. The change required a complex stress analysis, which in turn required measurement data across multiple airplanes. Tool Engineering was needed to support the data collection. Tooling fabrication, data collection across multiple airplanes, and the stress analysis took several months to accomplish.

The full project took more than a year and half to complete. I was a bit dejected by the length of time required to make this change. My manager recommended that I re-think my view of success. He reminded me that the project that took a year and a half to successfully complete included a change that eliminated a problem that had plagued our programs since the very first aluminum-passenger-plane wing. He was relieved that someone had finally stuck with it long enough to get the problem resolved."

– Jennifer MacKay

PROJECT TRACKING:

Successful project tracking is essential to project completion. Publicizing a project's status provides visibility and accountability for open action-items. It also provides leadership the information they need to adequately support the effort. Additionally, a project tracking system enables users to manage and organize multiple in-work projects simultaneously. Lastly, completed projects can be retained and made available for historical reference. A good tracking system includes easy access to data for all stakeholders such as a 4-Square, presentation, charter, Realitychart, and action-item list.

"Sadly, when projects are not tracked and action-items aren't completed some of the best solutions can fall by the way-side and never see implementation. I mitigate this by managing my projects via Sharepoint; at a glance project status, action-item responsibilities, and next steps can easily be viewed. This also allows access to all project information: 4-square, project presentation, Realitychart, data collection, meeting minutes, photos and videos."

– Jennifer MacKay

4-SQUARE:

A "4-Square" is a simple and effective tool that provides a quick overview of a project situation, reviewed causes, proposals/solutions, actions/steps, and a timeline of events. A 4-square should be updated at each major milestone of a project.

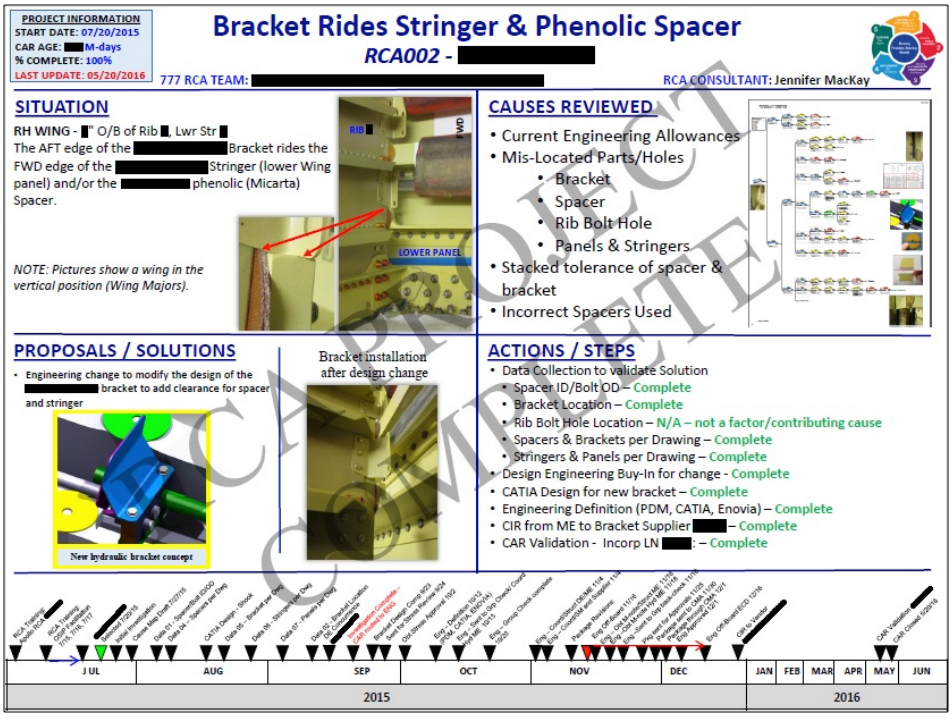

FIGURE 9: EXAMPLE OF AN RCA 4-SQUARE, PROPRIETARY INFORMATION HAS BEEN REMOVED

PROJECT PRESENTATION:

Compiling an overall project presentation is very useful for reporting to leadership and stakeholders; it also for provides a historical reference. A presentation should identify the team members, outline the problem, provide background information, explain the investigation and results, identify the causes and solutions selected, provide details about the implementation plan, and summarize the ROI.

ACTION-ITEM LIST: Creating and maintaining an action-item list supports project progression by assigning responsibility to a focal. It also provides estimated due-dates and actual completion dates to project tasks. An action-item list also tracks the status of individual tasks by assigning a percentage-completion value to each.

Tasks/Action Item Logs

Task Order	Action Item	Focal	Status	Additional Information	Held For	% Complete	Due Date	Completed Date
	Complete Action Plan 3 of [redacted]	[redacted]	Not Started					
	Assure Verification is set		Not Started	Assure CAR has been routed through ENGINEERING APPROVAL and verification is set.				
	Report differences between a [redacted] spacer.		Completed	• A [redacted] spacer has a diameter of 2.250". • A [redacted] Spacer has a daimter of 2.500" • Thickness determined by standard P/N callout.		100%	8/3/2015	8/3/2015
	Data 05 - Validate the [redacted] bracket is built per detail drawing [redacted] using PCM. Qty 5 Units. RCA Map ID 37		Completed	[redacted] brackets were per PCM		100%		8/21/2015
	Verify shop has a [redacted] spacer available.		Completed	The [redacted] Spacer translates into the following: [redacted] All Part are available		100%		8/5/2015
	DATA 01 - Evaluate [redacted] Spacer ID vs [redacted] Bolt OD		Completed	[redacted] bolt OD vs. spacer ID analysis [redacted] Bolt OD = .312 [redacted] Spacer ID = .400 Engineering tolerances allow a [redacted] of the spacer		100%		8/5/2015
	DATA 02 - Collect data to capture bracket location [redacted] Units starting on Line [redacted] Measurement to be taken from RIB stringer to 1st rivet hole (aft hole). Log findings within the [redacted] Bracket Location analysis ppt. RCA Map ID 21 & 25.		Completed			100%		
	Data 04 - Measure (qty 10) [redacted] spacers and validate they are built per drawing [redacted] Sheet 1. RCA Map ID 33		Completed			100%		8/17/2015
	Obtain DE Engineering buy in for new bracket design. RCA Map ID 39		Completed			100%		
	Incorporate new bracket design. RCA Map ID 41. ECD 12/16		Completed			100%		1/4/2016

FIGURE 10: EXAMPLE OF AN ACTION-ITEM LOG, PROPRIETARY INFORMATION HAS BEEN REMOVED

It's essential that an RCA package (4-Square, presentation, charter, Realitychart, action-item list):

- Shows real-time project status
- Communicates findings
- Establishes credibility
- Provides a visual that pulls the entire project together, especially when multiple groups are working on different parts of a solution
- Creates a basis for decision-making and funding approval
- Provides historical reference and knowledge for others

STEP 5 SUSTAIN THE GAINS

Sustaining the gains is the final step of the Boeing Problem Solving Model. This involves verifying that the solutions which have been implemented actually solved the problem without introducing other issues. Additionally, it's important to gather financial data and modify the ROI to include the actual gains achieved.

PROCESS IMPROVEMENT PROJECTS:

Sustaining the gains on process improvement solutions can be accomplished by conducting reviews on the implemented fixes. Witnessing a successful solution right after implementation is critical but it's equally as important to ensure the problem remains fixed. It's a good practice to conduct 30/60/90 day checks after solution implementation.

"A while back, a team of mine came up with a solution to a difficult problem — the problem involved 7 locations of recurring defects on a horizontal stabilizer. When we finally resolved the issue the team met on the factory floor to witness the implemented fix. The first and second airplanes down the line resulted in 100% success; our team cheered and patted ourselves on the back for a job well done.

A year and a half later I was on the floor telling someone about this problem we had fixed and I introduced them to the lead mechanic involved on the project. I was explaining the success of the project when the mechanic said 'Yeah, but you only fixed five of the problem areas. There are still two where the solution doesn't work.' Apparently these two problems had been going on ever since airplane three, and no one ever told me. So, guess what my next assignment was… Because of this I now do a better job of following-up; I make sure the implemented solutions work as planned before closing the project."

– Jennifer MacKay

NONCONFORMANCE PROJECTS:

When a production part, installation, process, etc. doesn't conform to the engineering specifications a 'nonconformance' exists. These nonconformance projects can't be closed until the implemented solution(s) are validated on a production airplane. This acts as built-in verification system whereas process improvement projects need to be monitored.

CONCLUSION A SUMMARY

Incorporating the Apollo Root Cause Analysis Methodology and RealityCharting® software into the Boeing Problem Solving Model has been a very successful method for conducting Root Cause Analysis investigations.

"I've found that most people are problem solvers by nature but when they utilize structured methods, tools, and training their results are consistently more effective."
– Jennifer MacKay

ABOUT ARMS RELIABILITY

ARMS Reliability has worked with many companies worldwide to implement their performance improvement programs. By structuring programs to fit within the goals and objectives of the business, rather than applying a 'one size fits all' solution, effective and long lasting results are realized.

Learn the Apollo Root Cause Analysis methodology at our worldwide public training courses

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ARMS Reliability is an authorized global training provider of the Apollo Root Cause Analysis methodology.
RealityCharting® and RC Pro™ are the software tools that support the Apollo Root Cause Analysis methodology.