Quality 101 Session 2
Supplier Quality

ASQ Aviation, Space & Defense Division
Collaboration on Quality in the Space and Defense Industries (CQSDI) Forum
March 13, 2017

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Quality 101 Session Two (2:30 – 4:45 pm)

Agenda

• Supplier Quality Process
  – 2:30 – 2:55 Risk Identification and Mitigation
  – 2:55 – 3:05 Supplier Evaluation
  – 3:05 – 3:10 Supplier Approval and Selection
  – 3:10 – 3:25 Supplier Quality/Mission Assurance Requirements

• Activity 3:25 – 3:30

• Supplier Quality Execution
  – 3:30 – 3:45 Supplier Oversight
  – 3:45 – 3:50 Supplier Ratings - Scorecard
  – 3:50 – 4:05 Actions for Non-conformance - Root Cause Corrective Action

• Activity 4:05 – 4:40

• Summary and Resources 4:40 – 4:45
Supplier Quality Process
Supplier Quality Process

Managing Supplier Risk

Closed Loop System of Checks and Balances Manages Risk
Managing the Risk of External Providers

• Pre-Award Evaluation

• Source Selection, approval status, controlled use, Scope of approval – product type

• Purchase Order Coding for Quality Requirements

• Periodic reviews of supplier performance including process, products, services conformity, on-time delivery performance
  – Reviews types include Metrics for Supplier, Readiness Reviews and Discrepancy Reviews during Qual/ATP

• Product acceptance – inspections

• Supplier Ratings
  – Register of suppliers – approved, conditional, disapproved

• Actions for non-conformances – Root Cause/Corrective Action

Reference: AS 9100D 8.4 Control of Externally Provided Processes, Product and Services

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Risk Identification and Mitigation

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Managing Supplier Risk

- Why perform a risk assessment of suppliers
- What is the risk management process
- What are sources of supplier risk
- How to assess risk
- How to manage risk
- Mapping risk potential to mitigation strategies
Why Perform a Risk Assessment of Suppliers?

• It’s a requirement of AS9100 D
  – “The organization shall identify and manage the risks associated with the external provision of processes, products, and services, as well as the selection and use of external providers”

• Provides a basis for source selections

• Understanding of efforts to manage the risk
  – Technical, cost, schedule, sub-tier management

• Total cost and complexity of an acquisition
  – Disciplines, effort, level of skills to execute

They Contribute to Our Success
What is the Risk Management Process?

1. Identify risk
   Use Models to segment the supply base by supplier or product

2. Assess risk
   Probability and Impact

3. Choose mitigation strategy
   Map risks to mitigation strategies unique to each situation

4. Implement controls

5. Review controls
Potential Sources of Supplier Risk

- Cost vs. Competency
- Sub-tier supplier control
- Loss of critical skills
- Manufacturing site change
- Conversion of customer Requirements
- Process control
- Quality performance
- Counterfeit parts
- Requirements

Supplier Risk

Others?
A Quick View of Risk Assessment

• Within the aviation, space, and defense industry, risk is generally expressed in terms of the likelihood of occurrence and the severity of the consequences.

• A formal risk mitigation process addresses risks that exceed a defined criteria (such as endangers life, mission failure, loss of functionality).

• Focuses resources on highest risk.

References:

Methods to Manage Risk

• Early understanding of risk potential
• Ensure requirements are complete, accurate, unambiguous, verifiable
• Kick-off review performed by one or more disciplines depending on complexity
• Use engineering oversight
• Understand changes from baseline products
• Manufacturing readiness reviews
• Regular product reviews
• Challenge qualification by similarity
• Periodic QMS evaluation
• Customer source inspection / testing
• Incoming inspection and screening
• Robust testing
Segment by Product Classification

• Who is responsible for engineering?

• Where the product is in the life cycle?

• Map product types within the matrix
  – Quadrant 1 – Build-to-print and Off-the-Shelf
  – Quadrant 2 – Build-to-print and Development
  – Quadrant 3 – Build-to-Spec and Off-the-Shelf
  – Quadrant 4 – Build-to-Spec and Development

• Apply unique risk mitigation strategies

Reference: Aerospace Report No TOR-2011 (8591-18), Supplier Risk Evaluation and Control, June 1, 2011, TOR-2011
## Product Segmentation: Risk and Mitigation Strategies

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Prime’s Responsibility</th>
<th>Supplier’s Responsibility</th>
<th>Source of Technical Risk</th>
<th>Mitigation Strategies</th>
</tr>
</thead>
</table>
| Build-to-print and Off-the-Shelf | • Decide appropriateness of product  
• Create a drawing from Supplier’s to manage unique requirements | • Manufacturing processes  
• Standard product lists  
• Re-use of existing code | • Low technical/moderate quality risk  
• Changes in designs or processes, materials, site  
• Uses Qual by Similarity  
• Control of processes  
• Control of quality | • Pre-award evaluation of similarities of design and processes |
| Build-to-print and Development | • Engineering  
• Software design (data flows, hierarchy diagrams, data structures, etc.) | • Technology  
• Manufacturing capability and technology  
• Generates code  
• Performs software qualification testing | • High technical/ high quality risk  
• Assumptions of the supplier’s capabilities or process controls  
• Changes during development  
• Stability of supplier’s technical staff | • Careful reviews  
• Strong process controls |
| Build-to-spec and Off-the-Shelf | • Specifies requirements and buys suppliers standard product | • Standard product line  
• Development is complete  
• Configuration management  
• As-Is re-use of existing code | • Low technical/ low quality risk  
• Supplier makes minor changes and qualifies by similarity  
• Supplier changes material  
• Differences in application from intended use | • Engineering oversight by use of subject matter experts |
| Build-to-spec and Development | • Specifies requirements | • Engineering –reqmts to proof of design  
• Manufacturing capability  
• Code to requirements | • High technical/moderate quality risk  
• Prime must ensure supplier is applying mature technology (post PDR focus)  
• Supplier’s capabilities need to accommodate the complexity  
• Supplier’s ability to transition to production | • Thorough pre-award evaluation |

Reference: Aerospace Report No TOR-2011 (8591-18), Supplier Risk Evaluation and Control, June 1, 2011, TOR-2011
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Pre-Award Evaluation

• Is the supplier qualified to perform their anticipated work scope prior to commencing source solicitation and selection or contractual arrangement, including teaming agreements?

• Qualified suppliers will exhibit four key attributes:
  1. Compliance to an appropriate, functioning, Quality Management System
     Example: Industry standards, such as CMMI, ISO9001 and AS9100
  2. Possess adequate financial health and historically demonstrates reasonable financial stability
  3. Demonstrated capability, qualifications and technical maturity for the type of work under consideration
     Example: Special process validation audits by National Aerospace and Defense Contractors Accreditation Program NADCAP
  4. Adequate current and future capacity (both within the supplier and the supplier’s supply chain) to perform the work scope
Quality Management System (QMS)

- Industry standards CMMI, ISO9001 and AS9100 describe QMS elements
  - Significant improvements in quality, cost reductions, process repeatability

- Confirm that QMS certification is not merely “virtual” certifications

- Review the supplier’s documented procedures and implementation
  - Including specific methods for the supplier’s control of goods and services from his sub-tier suppliers
  - Must describe the supplier’s organizational structure and reporting lines, including clear delineation of responsibilities

- Scope should include all functions involved
  - Engineering, development, systems management and integration, production, installation, testing, support, modification and servicing of both the hardware and software of the products and services being procured

- Special process validation audits by third party entities such as National Aerospace and Defense Contractors Accreditation Program (NADCAP)
Financial Health Assessment

- Financial stability is essential to a supplier’s stable, predictable and dependable performance

- Means to identify potential risk, key in times of economic stress

- Various financial metrics to evaluate a supplier’s financial health
  - Current Ratio
  - Quick Ratio
  - Debt to Equity
  - Return on Sales
  - Return on Equity

- Credit Risk Monitor (CRM) service integrates several of them into an aggregated score

- Dun and Bradstreet (D&B) and Equifax offer similar estimate of financial distress for private firms without publically-available financial data

Incorporate into new supplier qualification & periodic reviews
Process Capability Assessment

- Ensures supplier is a good fit for the anticipated work scope
- Ensures supplier has the tools, processes and infrastructure to succeed
  - Capabilities, equipment, personnel, process controls and management systems
- Ensures robust sub-contractor selection and control
- Perform by subject matter experts
- Ensuring the supplier’s product level of technical maturity increases in line with the contract delivery schedule
Technical Maturity Level

- Definitions of product technical maturity from the U.S. Department of Defense (DoD), National Aeronautics and Space Administration (NASA), European Space Agency (ESA), European Commission (EC) and Oil & Gas Industry, US Department of Energy (DOE)

- **Level 1**: Undefined and not capable: No Process, Methods, Tools and/or inappropriate behaviours.

- **Level 2**: Defined and applied but not 100% effective or not applied everywhere in the company (capable for low risk products and services)

- **Level 3**: Defined, applied and effective: Repeated satisfactory performance capable.

- **Level 4**: Performance of proactive improvements towards planned targets, but not systematically on all processes / areas / products.

- **Level 5**: Best in class, continual improvement fully deployed, involving all stakeholders as part of company culture.

Capacity Assessment

- Evaluate the level at which a supplier is managing their workload
  - Entire plant
  - Cell level
  - Machine level

- Management of capacity at the lowest level is most desirable

- Is the supplier using capacity data for long range planning?

Warning Signs

- Pre-award evaluation elements may uncover indications of potential risk

**Quality Management System Verification**
- Quality Capacity
- QMS in-place and working
- CARS

**Financial Assessment**
- Credit Risk Monitoring (Frisk Score)
- Equifax Marginal Score
- Financial Ratios

**Process Capability Assessment**
- Capable for anticipated scope
- Tools, processes and infrastructure

**Technical Assessment**
- Technical Maturity (TRL)

**Capacity**
- Long range planning

Warning Signs

- Reliance on QMS certification only
- Defense business segment small
- Sales skewed to commercial
- Commercial decline/strike
- Self-financing
- Multiple sub-tier suppliers
- Work scope outside normal bounds
- Diminishing sources
- Key personnel change
- Employee turnover rate
- High absenteeism
- Lack of cross training
- Capacity shortages
- % Overtime
- Managing capacity at site vs. cell level

On-site visits provide valuable insight into supplier qualifications

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Assessment Results Example

- Radar map allows visual assessment of results
- Expected level is plotted against actual level for each category
- Shows strengths and weaknesses of each evaluation category
- Identifies gaps
- Accept gaps or decide on action plan to close

Reference: Supply Chain Management Handbook (SCMH), Section 4.1.3, Supplier Selection & Capabilities Assessment, International Aerospace Quality Group, 5-Jul-2013 [www.iagg.org/scmh](http://www.iagg.org/scmh)
Supplier Approval and Selection

- Elements in the approval process may include but are not limited to:
  - Risk assessment
  - Pre-award assessment
  - Performance history for existing suppliers
  - Data from certification bodies
    - AS9100 or ISO 9001 third party certification
  - Define who has the authority for approval status decisions and changes
  - Maintain a register of suppliers and their approval status
    - Example:
      - Approved
      - Conditional - Findings that need to be corrected but should not preclude approval but may assign Source Inspection to assure conformance
      - Disapproved - Findings need to be corrected and re-audited
    - Scope of approval may be based on product type or process family

- Select supplier considering past performance, risk and pre-award assessments, alignment of the complexity of the product or service and requirements to the supplier’s capability
Requirements to Supplier
Space and Military Procurement

- All procurements for Space and Military are subject to DFARS and most Export laws apply to defense articles. Requirements come from a number of sources.
Standard Terms and Conditions/Flowdown

- Quality Standards (AS9100/ISO9001)
- Material Authenticity (DFARS 252.246-7007), (SAE AS5553)
- REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) and RoHS Requirements
- Conflict Minerals
- Export/ITAR Requirements
- Right of Access
- Order of Precedence
- Notification of Manufacturer Location & Process Changes
- Certificate of Compliance Requirement
- FOD/ESD Program Requirements
- Data Retention (If other than ISO requirements)
- AS9006, Deliverable Aerospace Software Supplement for AS9100
- ISO/IEC 12207, Software Life Cycle Processes
- Capability Maturity Model Integration (CMMI) - Level 3 or higher, or Federal Aviation Administration DO-178 – Software Considerations in Airborne Systems and Equipment Certification.
Flow-down Requirements (Not Contract-Specific)

• Non-contract specific requirements include:
  – Requirements of ISO and AS9100 (International Standards Organizations)
    • Requirements for the approval of products, procedures, process and equipment, (ISO)
    • Requirements for the qualification of personnel, (ISO)
    • Quality management systems requirements, (ISO)
    • The identification and revision status of specifications, drawings, process requirements, inspection/verification requirements and other relevant technical data, (AS9100)
    • Requirements for design, test, inspection and verification, (AS9100)
    • Requirements regarding the need for the supplier to notify the Procuring Agency of nonconforming product and how to obtain approval for nonconforming product, (AS9100)
    • Requirements to notify the organization of changes in product and/or process, changes of suppliers, changes in manufacturing facility location, (AS9100)
    • Requirements regarding minimum record retention, (AS9100)
    • Right of access by Procuring Agency and their customer and regulatory authorities, (AS9100)

Most suppliers are certified by ISO/ AS9100. Others have a comparable Quality System approved by NGC.
Space Program Parts Specific Requirements

• **Single Lot/Date Code Requirement**
  – Most Space programs require shipments from a component suppliers be from a Single Lot/Date Code. This allows for easier identification of suspect product in the event of a GIDEP or product recall issue.
  – Each type of product will have specific technology requirements for traceability. A COC (Certificate of Conformance) or COA (Certificate of Analysis), which is traceable to the original manufacturer, is normally required.

• **As Built Parts List (ABPL), if required, for the lot presented from an assembly manufacturer.** The ABPL normally contains lot numbers from each part on the assembly to provide traceability of all electronics.

• **Most Space level parts have prohibited material referenced in the Source Control Drawing (SCD), referenced specification or drawing.**
  – Mercury and unalloyed tin plated surface >97% purity are examples

• **Most SPACE programs have a requirement that “REWORK” be approved just like a repair. This is a different concept of repair vs rework.**
Prohibited Materials

- **Metallic Restrictions**
  - Zinc, Cadmium, Mercury, Beryllium Oxide (BeO), Silver Plated wire with <40 micro-inches, gold plating over silver without a barrier metal, unalloyed tin plated surface >97% purity, etc.
  - No lock washers
  - Graphite

- **Non-Metallic Restrictions**
  - Silicone, Polyvinyl Chloride (PVC), one-part Acetic Acid Compounds, etc.
  - Polymers and Organic Outgassing materials
  - The use of hydrochloric acid, cadmium, chlorinated cutting oils and solvents, halogenated solvents, methyl alcohol, mercury, and silver in contact with titanium alloys

- All of these restrictions have a history of causing failures in a Space application. It is VERY important that the finished design and processes are reviewed for compliance.
Prohibited Materials

- Often, there will be a Space program requirement which details prohibited parts, materials and processes

| 1 | Radial leaded capacitor styles CVR41, CVR42, CVR43, CVR51, CVR52 and CVR53. |
| 2 | Mica capacitors per specifications other than MIL-PRF-87164. |
| 3 | Single-sealed CLR style wet slug capacitors. |
| 4 | Silver-based CLR style wet slug capacitors. |
| 5 | Aluminum electrolytic capacitors. |
| 6 | GKR65 style 1 microstrad ceramic dielectric capacitors. |
| 7 | All EMI or RF filters with tubular ceramic elements. |
| 8 | All fuses requiring fuse holders. |
| 9 | All relays with wire sizes less than 44 AWG. |
| 10 | Fixed film resistor chips with copper or nickel conductor films. |
| 11 | All non-hermetic hollow core (ceramic) film type resistors. |
| 12 | All hermetic hollow ceramic core film resistors with internal metallization. |
| 13 | All hermetic devices tested in accordance with MIL-ST2-883, Method 1014, Test Conditions D or E. |
| 14 | All MIL-DTL-16878 wire types except those with PTFE insulation which requires qualification. |
| 15 | All Polyvinyl Chloride (PVC) insulated wire and cable. |
| 16 | All connectors with wire wrap contacts. |
| 17 | All items with exposed surfaces of cadmium, zinc, magnesium, or selenium including, but not limited to, all hardware, fasteners, assemblies, mechanical structures, EEP parts, and connectors. These materials may be used inside hermetically sealed assemblies. |
| 18 | All items with any uncoated tin plated surfaces of greater than 97% purity, whether exposed, internal, concurrent or otherwise including, but not limited to, all hardware, fasteners, assemblies, mechanical structures, EEP parts, and connectors. |
| 19 | High volatility compounds that exceed the outgassing limits specified herein and do not have NSIMAR approval from the Prime. Allowed materials have a maximum permissible losses of 1.0% Total Mass Loss (TML) and 0.1% Volatile Condensable Material (VCM) when tested in accordance with ASTM E595. |
| 20 | Class I lico and duplicating chemicals. |
| 21 | Corrosive sealants and adhesives including, but not limited to, acetic acid evolving silicone materials. |
| 22 | Materials that exhibit or are known to exhibit natural radioactivity including, but not limited to, uranium, potassium, radium, thorium, and/or any alloys thereof. |
| 23 | Dissimilar metals exhibiting different galvanic potentials, including metal couples to graphite composites, shall not be used in conjunction with each other unless protected and separated by a suitable finish defined in MIL-STD-889. |
| 24 | Protective finishes on metals, including preparation, cleaning and application, shall be in accordance with MIL-G-SPEC-250 except zinc, cadmium, and tin finishes. |
| 25 | Plated metal surfaces where intended rotational interference may cause particulates. |
| 26 | Finish materials, especially bare silver that evolve particles as a result of handling or oxidation. |
| 27 | Aluminum alloys with a stress corrosion threshold in any grain direction less than 25 Ksi. |
| 28 | Use of the following aluminum alloys, where temperatures exceed 150°F: 5083-H32, 5086-H34, 5086-H38, 5456-H32 and 5456-H38. |
| 29 | Alloys or compounds containing mercury. |
| 30 | The use of mercury and mercuric compounds in conjunction with the manufacturing, storage, or use of aluminum or titanium alloys. |
| 31 | The use of devices containing mercury or mercuric compounds, including temperature sensing devices, during fabrication or utilization of space flight structures and subsystems. |
| 32 | Use of any of the following materials or with titanium during the manufacturing process are permitted if they are completely removed from the titanium during subsequent processing. Materials that can induce stress corrosion, hydrogen embrittlement, or reduce fracture toughness include: hydroniac acid, silver, halogenated solvents, methyl alcohol, mercury, mercuric compounds, trichloroethylene, trichloroethane, carbon tetrachloride, halogenated cutting oils, halogenated hydrocarbons, cadmium or silver plated clamps, tools, fixtures or jigs. |
| 33 | The brazing of both metals not covered by AWS C3.4; and the brazing of either cadmium or zinc alloys that have not been plated to preclude material hazards. |
| 34 | Fusion welding operations in the vicinity of brazed joints or other operations involving high temperatures which may affect the brazed joint. |
| 35 | Brazed joints shall be designed for shear loading and shall not be used to provide strength in tension for structural parts. |
| 36 | Corrosive solder fluxes unless detailed cleaning procedures are specified, along with appropriate verification methods to ensure removal of residual contaminants. Any such use requires prior approval. |
| 37 | Nichrome film resistors. |
| 38 | The use of glass body diodes are not preferred. Glass sealed parts, such as but not limited to glass sealed diodes, are prohibited. If these parts are to be approved, a risk mitigation plan must be reviewed and implemented as part of the part approval process. |
Screening

• **Typical Screening for Space Product**
  
  – Extended Clean-Room requirements for Space Manufacturing.
  – X-Ray for particles (FOD), attachment of devices to substrates and wirebonds, epoxy and solder coverage. (J-Std-001FS, MIL-PRF-38534/35, MIL-S-19500)
  – Pre-Cap for Hybrids(Mil-Perf-38534), Microcircuits High and Low Power (100% of the lot)
  – Non-destructive wire bond pulls
  – PIND testing (Particle Impact Noise Detection)
  – Extended Burn-In and Life Test requirements(320 vs 160 hrs)
  – Extended Vibration Tests(up to 10,000Gs)
  – Thermal cycling of raw cables, prior to connector attachment
  – Extended Vacuum Bake, prior to sealing
  – Limits on re-screening requirements (i.e. Rework)
  – Element Evaluation of Semiconductors, Microcircuits, passives, packages and epoxies
  – Unique Inspection criteria/ 100% inspection requirements/ Radiation Hardness requirements
For Additional Information…

- JEDEC 13 ([http://www.jedec.org](http://www.jedec.org))

- DLA Land and Maritime-VQ
  DLA Land and Maritime – QPL and QML Qualification/ Certification programs

- IPC-J-STD-001-FS - Space Applications Electronic Hardware Addendum to J-STD-001
  IPC J-STD-001F - Requirements for Soldered Electrical and Electronic Assemblies

- MIL-PRF-19500 - Semiconductor Devices, General Specification
  MIL-PRF-38534 - Hybrid Microcircuits, General Specification

- ISO 14644-1 - Cleanrooms and Associated Controlled Environments – Part 1: Classification of Air Cleanliness.
  ISO 14644-2 - Cleanrooms and Associated Controlled Environments – Part 2: Specifications for Testing and Monitoring to Prove Continued Compliance with ISO 14644-1
  Space(K or S) is Class 5 (100) vs Class 8(100,000) for Aerospace product(B or H)

  MIL-STD-883 - Test Methods for MICROCIRCUITS
  MIL-STD-1686 - Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts
  MIL-STD-1916 - DOD Preferred Methods for Acceptance of Product
  MIL-STD-1535 - Supplier Quality Assurance Requirements
Activity Preview
Supplier Performance Oversight
Supplier Performance Oversight Reviews

- Complex, first time builds require on-site design reviews to ensure all drawing requirements have been properly incorporated into the suppliers internal documentation. Work instructions, routers, outline drawings, etc., are reviewed for accuracy and thoroughness. These reviews also give an opportunity to answer any design questions, verify assumptions, and make sure everyone is on the same page.
  - These design reviews should include one or more of the following depending on the product.
    1. Specification Compliance Review
    2. Preliminary Design Review followed by a Critical Design Review
    3. Production Readiness Review
    4. Test Readiness Review
    5. Data Products Acceptance Reviews
  - Engineering, manufacturing, quality, and supply chain should all be involved for a successful design review.
Some products require in-process surveillance and/or inspection of key features prior to final assembly. Surveillance and/or inspection points are identified and incorporated into contractual and supplier production documentation to ensure they do not impact production schedules.

- In-process reviews or witness of product functionality (e.g., vibration and/or atmospheric testing, or mechanical functionality) may be accomplished by witnessing the test or by review of the test results, as required. Software in-process audits are performed during the development life-cycle.

- Inspection/test witness results, including failures or non-conformances, are documented and resolved in a similar manner as final test inspection findings and retained for nonconformance trending and capability assessments.
First Article Inspections (FAIs) are performed to ensure that a complete, documented physical and functional inspection process verifies that all prescribed production methods have produced an acceptable item as specified by the engineering drawing, purchase order and/or other applicable design documents. The FAI also provides objective evidence that all engineering, design and specification requirements are correctly understood, accounted for, verified and recorded.

- A full FAI is typically performed for new product, new supplier, new location of manufacture, a lapse in production of more than 2 years, or when required by the customer.
- A partial FAI /delta FAI should be performed for product changes. FAI is performed prior to product acceptance and/or shipment.

• Reference AS9102 “Aerospace First Article Inspection Requirement”
This is the final gate to acceptance and shipment of supplier product as required by the Purchase Order (PO) or Subcontract.

- Final inspection/testing includes review of deliverable requirements. Inspections/tests are conducted in accordance with engineering, PO and applicable specification standards. Supplier quality performance data and associated level of product risk may be used to determine the extent of product verification and validation activities.

- The inspection/testing processes ensures the deliverable meets contractual requirements. All required testing and inspection documentation shall be complete, accurate and available at the final inspection/test.

- Non-conforming product, test anomalies or failures are documented along with any rework/ retest required to bring the product into compliance, prior to final acceptance and shipment.

- This data is retained and provides the evidence/basis for suppliers’ quality ratings.
• Incoming/Receiving Inspection is verification check to review packaging (product was not damaged during shipment), identification/marking, paperwork (C of C’s, objective evidence that source inspection was completed if required), quantity, workmanship, and basic dimensional measurements.

• Certified (Dock to Stock) is used for low risk material with a proven track record, that can be received as “certified” material.
  – Paperwork is verified but physical inspection is waived.
• Site Survey/New Supplier Evaluation must be performed before a supplier can be added to the ASL (Approved Supplier List).
  – A business case is typically required to document why this supplier should be evaluated.
    • 2\textsuperscript{nd} source, unique product line, cost, etc.
  – Undergo an on-site evaluation consisting of core evaluations for the procured product technology and supplemental evaluations to assure compliance to specific customer requirements/flowdowns
  – Where applicable, maintain Government approval for the scope of work being considered (e.g., DSCC certification for MIL-PRF-19500 electronic components)
  – Approved by a 3\textsuperscript{rd} Party QMS System Cert (ISO-9001, AS9100)
Supplier Performance Oversight
Supplier Audits

• Product Audits of the supplier’s internal processes and respective quality management system elements are performed on-site. Audits are based upon the supplier’s commodity risk level and scorecard rating and/or other applicable risk elements.

• Process Verification Reviews provide for detailed examination of supplier processes. They generally include participation of other functional organizations and expertise, such as manufacturing, engineering and other disciplines as required to evaluate process effectiveness as well as compliance.
Supplier Ratings and Scorecards
Why Supplier Performance Ratings and Scorecards

• A supplier performance ratings database allows for analysis to identify opportunities

• Documenting a baseline for performance
  – Quality, delivery, cost, service, compliance, customer satisfaction

• Allows for trending that indicates changes
  – Is a supplier’s performance getting better or worse?

• Tool for use in source selection

• Provides objective information for a supplier award program

• Provides data on what areas need work

• Helps in planning audits, performance reviews and improvement projects

Basic Elements of a Supplier Scorecard

- Quality, Delivery and Cost

- Example
  - Quality – percentage of accepted delivered parts
  - Delivery – percentage of parts delivered on time
  - Customer Satisfaction – overall satisfaction with the supplier
  - Process Health/Lean – based on evaluations, surveillance results and supplier corrective actions
  - Weighting factors for each element

- Other elements to consider: Management, Technical, Financial, Sub-tier Management

- Who gets reports and how often?
  - Suppliers
  - Procurement and Quality Managers
  - Commodity Leads

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**Supplier Performance Rating Scorecard (4th Quarter 2016)**

<table>
<thead>
<tr>
<th>Scorecard Ratings</th>
<th>Scorecard Element</th>
<th>Possible Points</th>
<th>End Date 2016-12-31</th>
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Total Score

- Blue = 100-91
- Green = 90-75
- Yellow = 74-51
- Red = 50-0
Helpful Hints to Avoid Potential Rating Problems

• Guidelines, instructions, procedures, responsibilities must be documented and maintained

• Structure reports so they are organized and readable

• Database maintenance

• Timeliness of reports

• Ratings that are too general and don’t provide a discrimination in performance

• User friendly

• Management support

Actions for Non-conformances
Corrective Action Requests

- **Corrective Action Requests (CARs)** - is a formal notification from a Supplier Quality Management source, requesting the root cause and corrective action of nonconformities of a product, process, or service, with the objective of preventing recurrence.
  - Required by AS9100C in Aerospace/Space QMS

- **When to issue a CAR?**
  - **At Seller**
    - Source Inspection
      - If the non-conformance would have caused a factory rejection
      - Repeat issues (i.e. documentation, FOD)
    - Audits
      - Non-compliance could impact production hardware
      - To force the supplier to implement corrective actions
  - **At Buyer**
    - Factory floor and receiving inspection rejections when there is no source inspection
      - Workmanship defects
        » For damaged hardware, try to get confirmation that the hardware was received damaged
    - Issue CARs for systemic issues in which you have a documented trend
    - Minimize/limit CARs for missing documentation, single point electrical failure
    - Minimize/limit CARs for hardware receipts that are outside of the warranty time period
CAR Creation
Example for a Product Delivered to Buyer

• **Rejection description recommendations**
  – Clearly define the defect and how the material is non-compliant; what it should be vs how it was received
    • Site chapter and verse; specific drawing paragraph, PO note, MIL STD paragraph, IPC-610 section, etc.
  – Provide as much information as possible for the supplier to be able to investigate the issue
    • Date codes, lot numbers, serial numbers, RMA numbers, photographs
  – Highly recommend that hardware has been returned before issuing the CAR
    • Depending on the defect, it can be difficult, if not impossible for an effective root cause analysis to be performed without the material
    • Alternative can be photographs
  – If there are multiple defects; number them to make sure the supplier addresses each one

Poorly written reject description will result in a poor CAR response
Definitions

• **Root Cause:** The factor that, when corrected, eliminates the problem and its chance for recurrence
  – The most basic reason(s) for a problem, which, if corrected, will prevent recurrence of that problem.

• **Root Cause Analysis:** A systematic approach to get to the root cause(s) of a problem
  – Root cause analysis helps identify the true cause of a problem which leads to the right corrective action, thus preventing recurrence
  – The RCA process involves data/information collection, process mapping, root cause identification, recommendations for solutions, controlled test cases, implementation of corrective actions and an assessment of the effectiveness of the solution.
Symptom vs. Root Cause Approaches

If the supplier does a poor job of identifying the root causes of the problem, they will waste time and resources putting band aids on the symptoms of the problem.

<table>
<thead>
<tr>
<th>Symptom Approach</th>
<th>Root Cause Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Errors are often a result of worker carelessness.”</td>
<td>“Errors are the result of defects in the system. People are only part of the process.”</td>
</tr>
<tr>
<td>“We need to train and motivate workers to be more careful.”</td>
<td>“We need to find out why this is happening, and implement mistake-proofs so it won’t happen again.”</td>
</tr>
<tr>
<td>“We don’t have the time or resources to really get to the bottom of this problem.”</td>
<td>“This is critical. We need to fix it for good, or it will come back and burn us.”</td>
</tr>
</tbody>
</table>
Identifying Root Causes of a Problem

Grasp the situation.
Establish a clear definition of the problem and boundaries for the solution

Understand the way work is done – baseline the process

Filter and evaluate potential causes

Identify the true root cause factor that led to the problem

*SIPOC – Supplier-Input-Process-Output-Customer
**FTA – Fault Tree Analysis
The 5 Whys – Driving to Root Cause

What it is
• Asking “Why” is a simple technique used to analyze the causes of problems.

How to use it
• Asking Why simply involves repeatedly asking ‘why?’ (who, what, when, where, & how) until the answer is ‘because that’s the way it is’. At this point, it is likely that you have identified a root cause of the problem. If tackled and removed, the observed symptoms of the problem should also disappear.

How it helps
• Asking Why is a way of identifying the underlying root cause of a problem so that this can be tackled rather than dealing only with superficial symptoms.
• The magic “5” number of times “Why” is asked is only a guide and will work for most situations. However, you should continue to ask if the response is not one considered to be a root cause, or final response.
  – If too many “why’s” are asked, consider narrowing the scope of the inquiry, or dividing into multiple questions.
5-Why Example: High widget rejects

**Problem:** A factory is experiencing a high rate of widget rejects

1. **Why** is there a high reject rate of widgets?
   - *Because the plastic is stained.*

2. **Why** is the plastic stained?
   - *Because there is excess oil in the cutting machine.*

3. **Why** is there excess oil in the cutting machine?
   - *Because it is clogging as it is months since it was cleaned.*

4. **Why** is it so long since it was cleaned?
   - *Because we only service machines when they break down, not on a preventative basis.*

5. **Why** only service after breakdowns?
   - *Because maintenance say it is cheaper (but what about the cost of rejects and rework?).*
CAR Response

• In addition to the root cause, the CAR response must also address the following items:
  – Immediate Corrective Action and Containment
    • Rework of material, inspection of product on the manufacturing floor, stock pull, customer recall, etc.
  – Preventive Action
    • Update procedures/work instructions, training of inspectors/operators, etc.
  – Objective Evidence
    • Training records, copies of updated procedures, screenshot of new inspection step on their traveler, etc.
Activity
Summary of Supplier Quality Process

• Risk identification and mitigation
• Pre-award evaluation
• Source selection, approval status, scope of approval
• Requirements flow to suppliers
• Supplier oversight – reviews, audits, inspections
• Supplier ratings & scorecards
• Actions for non-conformance - Root Cause Corrective Action
Additional Resources
Additional Resources

- American Society for Quality (ASQ) Professional Certifications
  - Certified Quality Engineer - https://asq.org/cert/quality-engineer
  - Multiple other Professional Certifications Available at ASQ, General Catalog at:
    - https://asq.org/cert/catalog

| Biomedical Auditor (CBA)                  | Quality Improvement Associate (CQIA) |
| Calibration Technician (CCT)             | Quality Inspector (CQI)              |
| HACCP Auditor (CHA)                      | Quality Process Analyst (CQPA)       |
| Lean Certification                       | Quality Technician (CQT)             |
| Manager of Quality / Organizational Excellence (CMQ/OE) | Reliability Engineer (CRE) |
| Master Black Belt (CMBB)                 | Six Sigma Black Belt (CSSBB)         |
| Pharmaceutical GMP Professional (CPGP)   | Six Sigma Green Belt (CSSGB)         |
| Quality Auditor (CQA)                    | Six Sigma Yellow Belt (CSSYB)        |
| Quality Engineer (CQE)                   | Software Quality Engineer (CSQE)     |
|                                         | **NEW** Supplier Quality Professional (CSQP) |
Additional Resources

• BS and MS in Quality Assurance
  – Fully Accredited Online Program at CSUDH
  – BSQA - http://www4.csudh.edu/qa-bs/index
  – MSQA - http://www4.csudh.edu/qa-ms/index

• International Aerospace Quality Group - http://www.sae.org/iaqg/

• Automotive Industries Action Group - http://www.aiag.org/quality

• Most primes (Boeing, Lockheed, Northrop, etc.) have supplier pages with a wealth of information on their supplier requirement, great material for process control, FOD, ESD, etc. Well worth exploring to see how your customers approach quality in the supply chain.
Authors Biographies
Anne Hennessy has enjoyed a 35 year career in the Aerospace and Defense Industry. She is currently managing Supplier Quality for Space ISR Systems Division of Northrop Grumman, Mission Systems Sector. Her key initiatives focus on identifying and managing supplier risk early in the acquisition process. In her five years in Supplier Quality, she led projects ranging from improving inspection effectiveness to a project to develop a Secure Software Strategic Plan. She is a trained Six Sigma Greenbelt.

Previously she served in various design and leadership assignments in Hardware Engineering where she reduced design cycle time by 30%, documented design processes using Value Stream Mapping, established design guides and standards, such as TRL gap analysis and Requirements Compliance Matrix. Throughout her years in engineering, she built a strong background in microwave and microelectronics design starting her career at General Electric Space Systems Division where she designed solid state amplifiers for satellite communications equipment.

She holds a Master of Science degree in Technical Management from Johns Hopkins University and a Bachelors of Science in Electrical Engineering from Temple University.
Rick Coberly holds a Masters in Engineering Management and Bachelors of Science in Electrical Engineering. He has over 30 years of experience at Northrop Grumman in Supplier Mission Assurance/Procurement Quality Engineering. He managed the Supplier Mission Assurance organization for twelve of those years. He started his career in Reliability Engineering. He is experienced in conducting audits and assessments in ISO9002: 2008 Quality Management System (QMS) that includes Quality, Supplier, Systems and Program Assurance processes consistent with international QMS standards. He is a Certified Six Sigma Green Belt and has applied Knowledge of Root Cause Corrective Analysis (RCCA) techniques. He is an ASQ Certified Quality Manager and Certified Quality Auditor. He is currently a member of JEDEC JC-13/G12 Committee.
Dave Newton is a Supplier Quality Fellow Engineer with 13 years’ experience at Northrop Grumman Corporation and is currently supporting the Space ISR Systems Division in Baltimore, MD. He has a Masters and Bachelors of Science in Electrical Engineering from North Carolina State University. Specializes in providing supplier quality oversight for RF/microwave products, power supplies, CCA’s, and LTCC’s. He is also a certified Six Sigma Green Belt and a JEDEC G19A committee member.
James Banks, Jr., joined the Northrop Grumman organization in 2007 as part of the Professional Development Program – designed to provide new college hires an opportunity to experience multiple rotations in the core areas of the business. During this time, he worked in various organizations, including the Low Noise Power Supply group, Engineering Technical Development, Calibration & Product Services, and finally a rotation in Process Excellence. It was during his rotation in the Process Excellence organization that he was first introduced to Supplier Quality.

After deciding to take a permanent position within Supplier Quality, James never looked back. During his tenure as a Supplier Quality Engineer, he has led many continuous improvement initiatives and has become known as a resident Subject Matter Expert when it comes to First Article Inspection methodologies. He is currently working as a Supplier Quality Engineer within the Space ISR Systems Division of Northrop Grumman, Mission Systems Sector. He holds a Bachelor of Science in Electrical Engineering from North Carolina State University.
THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN
Back Up – Risk Example
## JSC Risk Scorecard

### LIKELIHOOD RATING

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Very Likely - Expected to happen. Controls have minimal to no effect.</td>
</tr>
<tr>
<td>4</td>
<td>Likely - Likely to happen. Controls have significant limitations or uncertainties.</td>
</tr>
<tr>
<td>3</td>
<td>Possible - Could happen. Controls exist, with some limitations or uncertainties.</td>
</tr>
<tr>
<td>2</td>
<td>Unlikely - Not expected to happen. Controls have minor limitations or uncertainties.</td>
</tr>
<tr>
<td>1</td>
<td>Highly Unlikely - Extremely remote possibility that it will happen. Strong controls in place.</td>
</tr>
</tbody>
</table>

### SEVERITY

- **High** - Mitigate; implement new processes, change requirements, or re-baseline
- **Moderate** - Manage/consider alternative processes, or Accept
- **Low** - Manage within normal processes; or Close

### JSC Risk Matrix

#### LIKELIHOOD

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Red</td>
</tr>
<tr>
<td>4</td>
<td>Yellow</td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
</tr>
<tr>
<td>2</td>
<td>Yellow</td>
</tr>
<tr>
<td>1</td>
<td>Green</td>
</tr>
</tbody>
</table>

#### CONSEQUENCE

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>Minor injury; Minor OSHA violation</td>
</tr>
<tr>
<td>System, Facility</td>
<td>Minor damage to asset</td>
</tr>
<tr>
<td>Environment</td>
<td>Minor or non-reportable hazard or incident</td>
</tr>
<tr>
<td>Performance</td>
<td>Minor impact to mission objectives or requirements</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Minor impact or reduced effectiveness</td>
</tr>
<tr>
<td>Workforce</td>
<td>Minor impact to human capital</td>
</tr>
<tr>
<td>Organizational or CMO Impact</td>
<td>&lt;2% Budget increase or &lt;$1M CMO Threat</td>
</tr>
<tr>
<td>Schedule</td>
<td>Minor milestone slip</td>
</tr>
<tr>
<td></td>
<td>Project milestone slip; No impact to a critical path</td>
</tr>
<tr>
<td></td>
<td>Major milestone slip; Impact to a critical path</td>
</tr>
</tbody>
</table>

### COST

- <2% Budget increase or <$1M CMO Threat
- 2-5% Budget increase or $1M-$5M CMO Threat
- 5-10% Budget increase or $5M-$10M CMO Threat
- 10-15% Budget increase or $10M-$60M CMO Threat
- >15% Budget increase or >$60M CMO Threat

### SCHEDULE

- Minor milestone slip
- Schedule margin available
- Project milestone slip; No impact to a critical path
- Major milestone slip; Impact to a critical path
- Failure to meet critical milestones

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Approved for Public Release
RISK DEFINITIONS

RISK MANAGEMENT: An organized, systematic process to effectively identify and analyze the risk of performance shortfalls, develop mitigation options, and implement approved mitigation strategies to reduce or eliminate risk likelihood and/or consequence. The RM process includes two key components: Risk-Informed Decision Making and Continuous Risk Management (see below).

RISK: A potential threat with negative consequence to safety, Center-controlled cost or schedule, or mission objectives for which a resolution is unlikely without focused management attention; or potential inability to fully implement agreements with NASA stakeholders or partners (commercial, governmental, international).

Top Center Risk: Requires Center Management resources or direction to resolve; could have cross-cutting impacts that affect two or more JSC organizations.
Top Directorate Risk: Requires Directorate Management direction and/or resources to resolve; affects one or more Directorate organizations, or other organizations.
Top Organizational Risk: Requires Division Management direction and/or resources to resolve; affects one or more sub-organizations.

CONCERN: A candidate risk with insufficient or immature information to analyze or define mitigation options. Can be managed internally within existing resources and processes.

RM PROCESS

Risk-informed Decision Making (RIDM): To inform JSC decision-making through use of quantitative and qualitative risk information to establish baseline performance requirements for mission support organizations, programs and projects.

Continuous Risk Management (CRM): To manage risk associated with the implementation of baseline performance requirements.

Writing a Risk Statement

GIVEN
There is a POSSIBILITY that, Will occur

CONDITION

CONSEQUENCE

Must be a fact
No uncertainty
Short and concise

CONSEQUENCE CATEGORIES

HSE: Health, Safety and Environment – Avoiding risk to:
Personnel Safety: Employee safety in accordance with OSHA regulations as well as the general public that may be impacted by NASA activities.
Facility/System Safety: Safety of NASA facility and system assets, including but not limited to, buildings, property/equipment, hardware and information technology.
Environment: Protecting the environment from adverse effects (e.g., leaks), in accordance with Federal (EPA/OSHA), State, and local regulations; and NASA assets from the effects of the natural environment.

Technical: Characterized as technical performance to baseline and quality requirements:
Performance: Ability of a Center organization, program or project to execute the mission; including the ability to comply with Federal, State, and local regulations.
Center Capabilities: Infrastructure and resources required to support Center organizations, programs and projects.
Infrastructure: Hazards / failures related to physical, information and security assets
Workforce: Ability to attract, retain and effectively utilize the requisite knowledge base/critical skills.

Cost: Mitigation strategy exceeds budget, defined as a % of DLO budget or a dollar amount of CMO funding needed.
Funding priority is established by the risk-owning organization expressed as a cost threat level:
Level 1: Greater than 50% probability of being realized
Level 2: 50-50%
Level 3: Less than 50%

Schedule: Ability to complete requirements by designated dates.