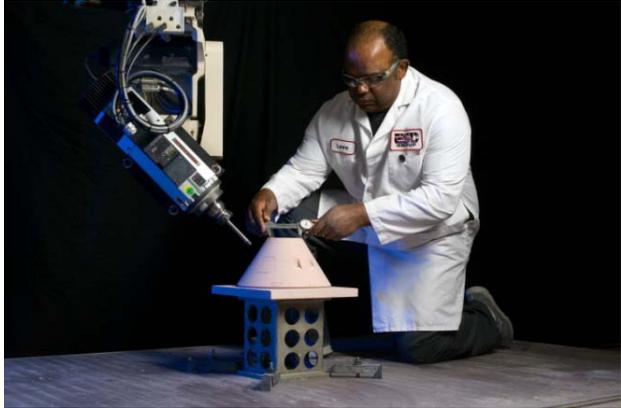


Manufacturing Services

Manufacturing Planning Guide



National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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1.0 Manufacturing Facilities

The manufacturing facilities at the Johnson Space Center (JSC) provide the resources, materials, and labor necessary to produce quality flight, ground support, and prototype hardware. We offer more than 130,000 square feet of manufacturing real estate. JSC offers experience and expertise in precision machining, sheet metal fabrication, welding, cleaning, hydrostatic testing, coatings, soft goods, metal finishing, heat treating, models and plastics, and assembly. This document is provided as a guide to utilizing JSC's Manufacturing Services.

Services Provided

- Flight and unique hardware fabrication
 - Specialize in new and one-of-a-kind hardware
 - Fabrication direct from model/print
- Composite manufacturing
 - Advanced composite materials, such as graphite or boron, in construction of advanced space structures
- Precision machining and R&D
 - Manual and CNC lathes and mills
 - Capacities from micro to large 3- and 5-axis milling
- Welding
 - GTAW, GMAW, SMAW, silver brazing, and friction stir welding
- Precision sheet metal fabrication
- Softgoods fabrication
 - Expandable structures
 - Softgoods for EVA hardware and tools
 - MMOD ballistic debris shields
- Metal finishing and surface preparation
 - 26" – 30" x 24" x 60" process tanks
 - Type 2 anodizing up to 30" x 15" x 60"
- Heat treating
- Models and plastics
- Precision cleaning (Class 50 – 1000)



Point of Contact

Manufacturing Manager, Samuel Daugherty
 Johnson Space Center
 2101 NASA Parkway, Houston, TX 77058
 (281) 483-7304
samuel.w.daugherty@nasa.gov

Capabilities

Service	Capabilities	
Machining	<u>Lathes</u> <ul style="list-style-type: none"> X, Y, and Z travel up to 22" x 6" x 40" 2 CNC lathes, 2 CNC mill/turn lathes 6 manual lathes 	<u>Milling</u> <ul style="list-style-type: none"> 3-, 4-, and 5-axis milling machines X, Y, and Z travel up to 64" x 40" x 32" 20 vertical mills <u>EDM</u> <ul style="list-style-type: none"> 2-wire and 1 RAM EDM X, Y, and Z travel up to 31" x 21" x 19" 3 EDMs
Additive Machining	Build fully dense structures directly from 3D CAD model. Applications include the following: <ul style="list-style-type: none"> Rapid alloy screening Composite research Rapid fabrication Advanced product development 	<u>Capabilities</u> <ul style="list-style-type: none"> 3 axes standard: XY linear/Z gantry motion 300 mm³ work envelope ± 0.25 mm positional accuracy Gas purification O² < 10 ppm
Welding	<u>Welding</u> <ul style="list-style-type: none"> Certification in accordance with AWS B2.1 MIG, TIG, pulse MIG, and stick welding Qualifications for: GTAW, GMAW, SMAW, and silver brazing Orbital tube welding Plasma cutting, arc gouging, and track burning 	<u>Friction Stir Welding</u> <ul style="list-style-type: none"> 5 axes, 7 degrees of freedom 25" x 40" x 80" work envelope Conventional, adjustable pin, and self-reacting welding modes High strength, low residual stress welds Dissimilar metals joining Ferrous and nonferrous metals
Sheet Metal Fabrication	The Sheet Metal Shop contains a wide variety of equipment for sheet metal fabrication, including manual and CNC shears, press brakes, and high speed punching machines. Available equipment includes the following: <ul style="list-style-type: none"> 120-ton CNC press brake with 12' bed, angle accuracy ± 1 degree 23-ton manual press brake, 60" bed Cincinnati 250 12' power squaring shear, capacity up to ¼" mild steel Pipe bending Niagara 10' power squaring shear, capacity up to ½" mild steel Heat treating furnaces capable of heating cycles up to 1,800 °F Large capacity automated material saw, capacity up to 20" solid stock 	
Heat Treating	<ul style="list-style-type: none"> Recirculating air furnace: 1,400 °F max., 72" (d) x 48" (w) x 28" (h) chamber, calibrated per AMS 2750 at 300 °F and 1,000 °F Still air (or inert gas) furnace, 2,000 °F max., 18" (d) x 18" (w) x 20" (h) chamber, calibrated per AMS 2750 at 1000 °F and 1800 °F <ul style="list-style-type: none"> 60-gallon quench tank filled with UCON RL (medium oil substitute) 60-gallon quench tank filled with water 	
Manufacturing Engineering	<ul style="list-style-type: none"> Design for manufacturability Design review Design for cost savings Process detail 	

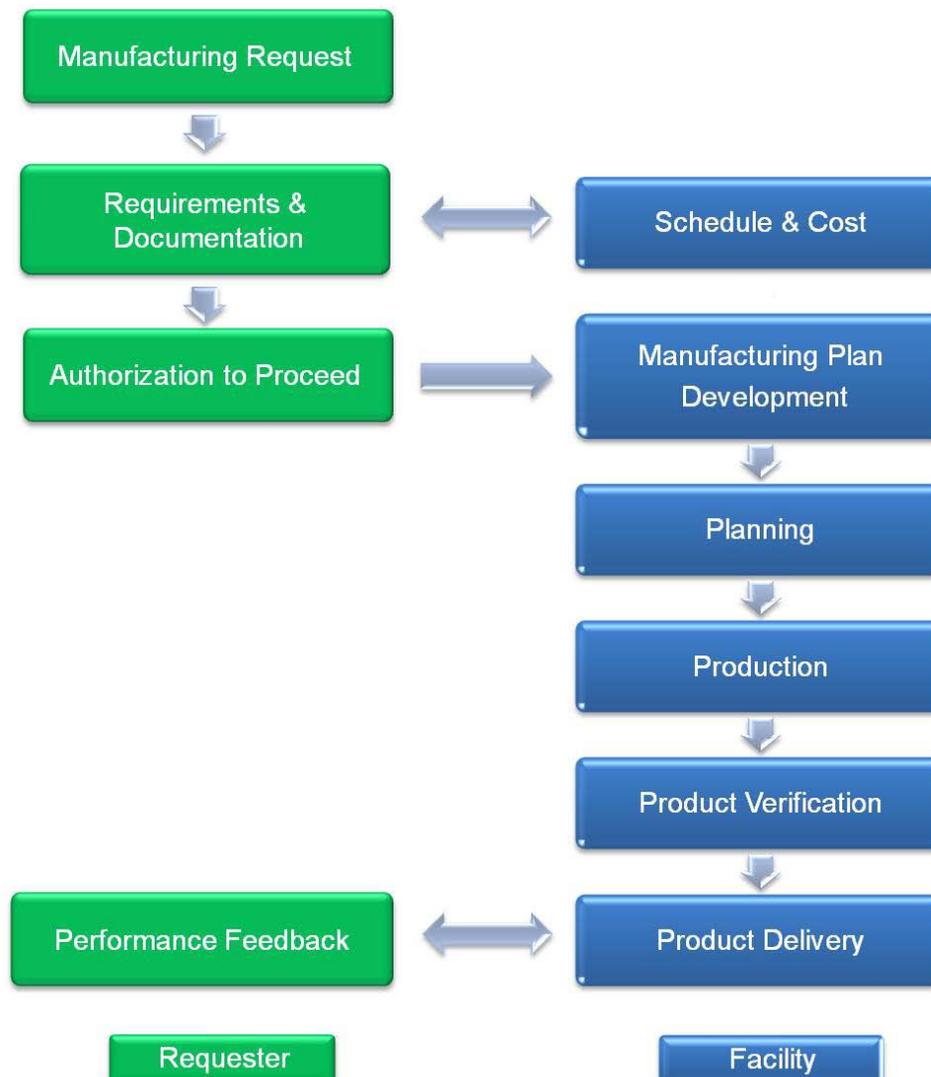
Service	Capabilities
Soft Goods and Inflatable Fabrication	<p>Highly qualified technicians operate a variety of sewing equipment, as well as shears, punches, scissors, and sealers. Capabilities include the following:</p> <ul style="list-style-type: none"> • Multilayer insulation • MMOD ballistic debris shields • Inflatable habitats • Thermal covers and containers • Expandable structures • Heat sealer (104" x 50")
Composites Manufacturing	<p>Capability to develop advanced composite materials application, such as graphite, boron, and numerous plastic media type materials, in the construction of advanced space structures:</p> <ul style="list-style-type: none"> • 2 autoclaves (7' x 16' and 2' x 4') <ul style="list-style-type: none"> – Curing epoxies and other resins – Foams, plastics, and composites • 4 ovens <ul style="list-style-type: none"> – Up to 5' x 8' x 6' – Temperatures up to 600 °F • Thermwood 5-axis router (120" x 120" x 36") • Class 100,000 clean area <ul style="list-style-type: none"> – Temperature/humidity controlled – Greater than 30' x 30' of assembly area – Assembly not requiring precision clean room – Assembly of composites requiring temperature/humidity control
Metal Finishing	<ul style="list-style-type: none"> • Passivation of stainless steels • Pickle mild steel: nitric acid/hydrofluoric acid • Chemical concentration testing (titrations) • Color anodizing • Alodine coatings for aluminum • Portable chemfilm touchup repair service • Paints, lacquer, and lubricants • Paint booths (256 ft² and 50 ft²) • ASTM B-117, Salt Fog Testing for Corrosion Performance <ul style="list-style-type: none"> – Ambient – 120 °F – Ambient – 100% humidity – Tests corrosion resistance of test coupons to simulate finished products in a harsh humid, salt-containing environment
Precision Cleaning	<p>Provides capability to precision clean flight hardware, components, aircraft parts, and small sensitive pressure gauges:</p> <ul style="list-style-type: none"> • Class 1,000 precision clean room • Precision levels 50 – 1,000
Models and Plastics	<ul style="list-style-type: none"> • CNC engraver <ul style="list-style-type: none"> – Signs up to 22" x 47" – 3 fonts and braille capability • 2 joiners (15" x 10" and 24" x 10") • 1 planer (8" x 24") • 3 table saws (up to 10' x 10') • 2 panel saws (up to 9' x 10') • 3 bead blasters (up to 3' x 3') • 1 large sanding booth • 2 lathes (10" x 36" and 18" x 60") • 2 band saws (20" and 18" throat)
Nondestructive Evaluation	<ul style="list-style-type: none"> • Real-time, digital, and film X-ray • Automated ultrasonic (conventional and phased array) • Fluorescent penetrant • Magnetic particle • Infrared thermography • Eddy current
Product Verification	<ul style="list-style-type: none"> • Quality inspection expertise <ul style="list-style-type: none"> – Coordinate Measuring Machine (CMM) operators – Dimensional inspection – Soft goods specialists • Precision measurement instruments <ul style="list-style-type: none"> – 3 CMMs – 2 optical comparators – 2 granite surface plates

2.0 Safety and Health

Safety is an integral part of the culture at the National Aeronautics and Space Administration (NASA). Management, leadership, and employee involvement from all organizations is critical to the success of NASA's safety program. In order to ensure personal safety and a safe environment throughout the manufacturing process, visitors must be escorted through the manufacturing facilities at all times. The requester shall follow all facility-specific safety and health requirements during site visits. Safety glasses with side shields must be worn while touring JSC's manufacturing facilities.

3.0 Manufacturing Process Flow

The flowchart presented below outlines the basic roadmap and significant milestones between the initial manufacturing request and delivery of your product. The flow is separated between Requester actions and Facility actions, highlighting interactions and inputs between the Requester and the Manufacturing Point of Contact (POC).



3.1 Export Controlled and Proprietary Information

JSC provides for protection of export controlled and proprietary information and hardware throughout the manufacturing process. The Requester shall clearly mark all export controlled or proprietary designs and data provided with a notice of restriction on disclosure or usage. The Manufacturing POC shall safeguard export controlled or proprietary items from unauthorized use and disclosure and ensure that designs and products remain secure within the facility and are properly sequestered. Access to the facility is restricted to facility personnel and escorted visitors. Designs shall be returned to the Requester or disposed of in accordance with the Requester's instructions upon product acceptance.

3.2 Manufacturing Request Phase

The manufacturing request phase establishes the relationship between the Requester and the Manufacturing POC. The Requester shall provide a Manufacturing Request Worksheet to the Manufacturing POC, which will be used to determine product feasibility and to develop an estimated cost and a preliminary manufacturing schedule. An initial manufacturing requirements review shall define the scope of the work, quantities, and desired delivery dates.

Inputs: Requester provides manufacturing request, identifies Technical Expert

Activities: Manufacturing POC reviews request to determine feasibility

Outputs: Facility delivers preliminary manufacturing plan, estimated cost, and schedule to Requester

3.2.1 Manufacturing Request

The manufacturing request outlines the scope of the work, quantities, and desired delivery date and includes drawings and/or sketches of the product. A Manufacturing Request Worksheet is provided in Appendix B. This worksheet addresses the basic requirements for utilizing JSC's manufacturing services. It is suggested that the Requester complete this worksheet to facilitate the development of a preliminary manufacturing plan and cost estimate. Contact the Manufacturing POC if you have any questions about completing the Manufacturing Request Worksheet. At a minimum, the manufacturing request should include the following information:

Scope of Work

A description of the product(s) to be fabricated, including, but not limited to, the following:

- Technical POC
- Statement of work
- Description of product
- Quantities
- Target delivery date(s)

Manufacturing Requirements

A description of the manufacturing requirements, including, but not limited to, the following:

- Dimensions (provide drawings, sketches)
- Tolerances
- Process specifications (e.g., military specifications, standards)
- Material specifications
- Materials to be supplied by Requester/procured by JSC
- Assembly requirements
- Product verification
- Special considerations (e.g., hazards, cleanliness requirements)

3.2.2 Schedule and Cost Estimate

A cost and schedule estimate, including major milestones, will be delivered following receipt of the Manufacturing Request Worksheet.

3.3 Manufacturing Planning Phase

The manufacturing plan and schedule are finalized during the manufacturing planning phase. The Requester shall provide detailed manufacturing requirements and product documentation to the Manufacturing POC.

Inputs: Requester provides manufacturing requirements and product documentation

Activities: Facility develops manufacturing plan, begins planning manufacturing and assembly

Outputs: Requester approves manufacturing plan and schedule
Facility begins production

3.3.1 Manufacturing Requirements

A complete understanding of manufacturing requirements is mandatory. Manufacturing requirements must be defined and reviewed so that the manufacturing team can properly prioritize, plan, and schedule the job. The Requester shall provide a detailed list of manufacturing requirements, including, but not limited to, the following:

- Materials specifications
- Drawings
- Process specifications

- Assembly instructions
- Product verification requirements [e.g., dimensional inspection, nondestructive testing (NDT)]

3.3.2 Product Documentation

Drawings/Models

The Requester shall provide detailed drawings, models, or equivalent information for the product to be manufactured. This information shall be used as the controlling document in manufacturing the requested product. Computer-Aided Design (CAD) models and drawings are both acceptable. We encourage you to submit electronic copies of your drawings. We can accept files through a File Transfer Protocol (FTP) site, by e-mail, or via standard mail. Acceptable file formats and the drawing submittal process are further described in Appendix A. Potential for misinterpretation of designs and drawings without dimensions or tolerances can lead to increased time and cost. Design and drawing considerations for manufacturing are included in Appendix A.

Materials Specifications

The Requester shall provide a list of materials required in the fabrication of the product. It is recommended that the Requester also provide the materials specifications or reference the materials specifications in the drawing. The materials specifications contain standard reference data for specific materials. Reference material data includes the measured physical property allowable, material-specific safety precautions, and material-specific processing parameters, such as heat treatment schedules, cutting speeds, and storage requirements. This data is needed during the execution of standard manufacturing operations. We can directly procure materials or fabricate from materials provided by the Requester. The Requester shall identify materials to be supplied for the requested work.

Process Specifications

The Requester shall provide a list of processes required in the fabrication of the product. It is recommended that the Requester reference the process specifications in the drawings.

Assembly Instructions

The Requester shall provide detailed instructions for assembly of the requested product. Assembly instructions should be included as flags or notes in the drawings or as a separate attachment referenced in the drawings.

Product Verification

The Requester shall define product verification requirements. Product verification may include dimensional inspection, test coupons, as-built prints, nondestructive evaluation, weld

inspection, or material certification. The Manufacturing POC will submit a manufacturing data package, including all requested product verification reports and the completed product.

3.3.3 Manufacturing Plan (If Requested)

An optional manufacturing plan may be prepared by the Manufacturing POC if required by the Requester. The manufacturing plan will include, at a minimum, the objectives, scope, manufacturing processes, materials, inspection requirements, and proposed delivery dates. The final manufacturing plan shall be approved by the Requester with concurrence from the Manufacturing POC. The manufacturing plan and drawings will be the controlling documents, with respect to scope and approach for product manufacturing.

3.3.4 Manufacturing Schedule

A detailed schedule shall be developed by the Manufacturing POC and approved by the Requester. The schedule shall allow adequate time for manufacturing, assembly, finishing, inspection, and delivery. The manufacturing schedule is highly dependent on the complexity of the request, part count, and extent of processing required. The workload in affected work centers will be reviewed, and potential conflicts shall be addressed by the Manufacturing POC.

3.4 Production Phase

Following approval of the manufacturing plan, the Manufacturing Planner will schedule the work. JSC encourages Requester participation throughout the manufacturing process.

Inputs: Approved manufacturing plan, authorization to proceed
 Activities: Facility completes manufacturing, assembly, and finishing
 Facility completes product verification
 Outputs: Completed product

3.4.1 Site Visit

Site visits to inspect work in progress are welcome but must be coordinated through the Manufacturing POC. Requirements for accessing JSC are covered further in section 4.0.

3.4.2 Product Verification

JSC is AS 9100 certified and provides inhouse quality services for dimensional inspection, NDT, and weld inspection. Product verification, in accordance with the defined requirements, will be performed throughout the manufacturing process. JSC will make reasonable accommodations to provide the Requester access to the Manufacturing Services facilities for the purposes of inspection, surveillance, and audit, thereby verifying that products are being fabricated per the defined requirements. The Requester shall provide advance notice of plans to send personnel to perform inspection of products.

3.4.3 Change Request

Changes to the design or drawings shall be approved by the Requester or Technical Expert. Deviations that result in a major change to the scope of the work may require a delta requirements review or a change to the cost and schedule. Changes should be coordinated through the Manufacturing POC.

3.5 Product Delivery Phase

The final product and the manufacturing data package shall be delivered to the Requester. The Requester shall notify the Manufacturing POC upon receipt of the product. Acceptance of the product concludes the manufacturing activity.

Inputs: Completed product

Activities: Facility ships/transport product to Requester

Manufacturing POC delivers manufacturing data package (if requested) to Requester

Outputs: Requester accepts product

Requester completes Customer Feedback form

3.5.1 Manufacturing Data Package (If requested)

The Requester shall define inspection reports and traceability requirements to be included in the manufacturing data package submitted upon completion of the job. Optional reports include dimensional inspections, weld inspections, welder certifications, materials certifications, as-built drawings, material test reports, or cleanliness certifications. Manufacturing Data Package requirements should be identified on the Manufacturing Request Worksheet (Appendix B).

3.5.2 Product Delivery

The Requester shall provide detailed instructions for packaging and delivery of the final product. Packaging and delivery requirements should be identified on the Manufacturing Request Worksheet (Appendix B).

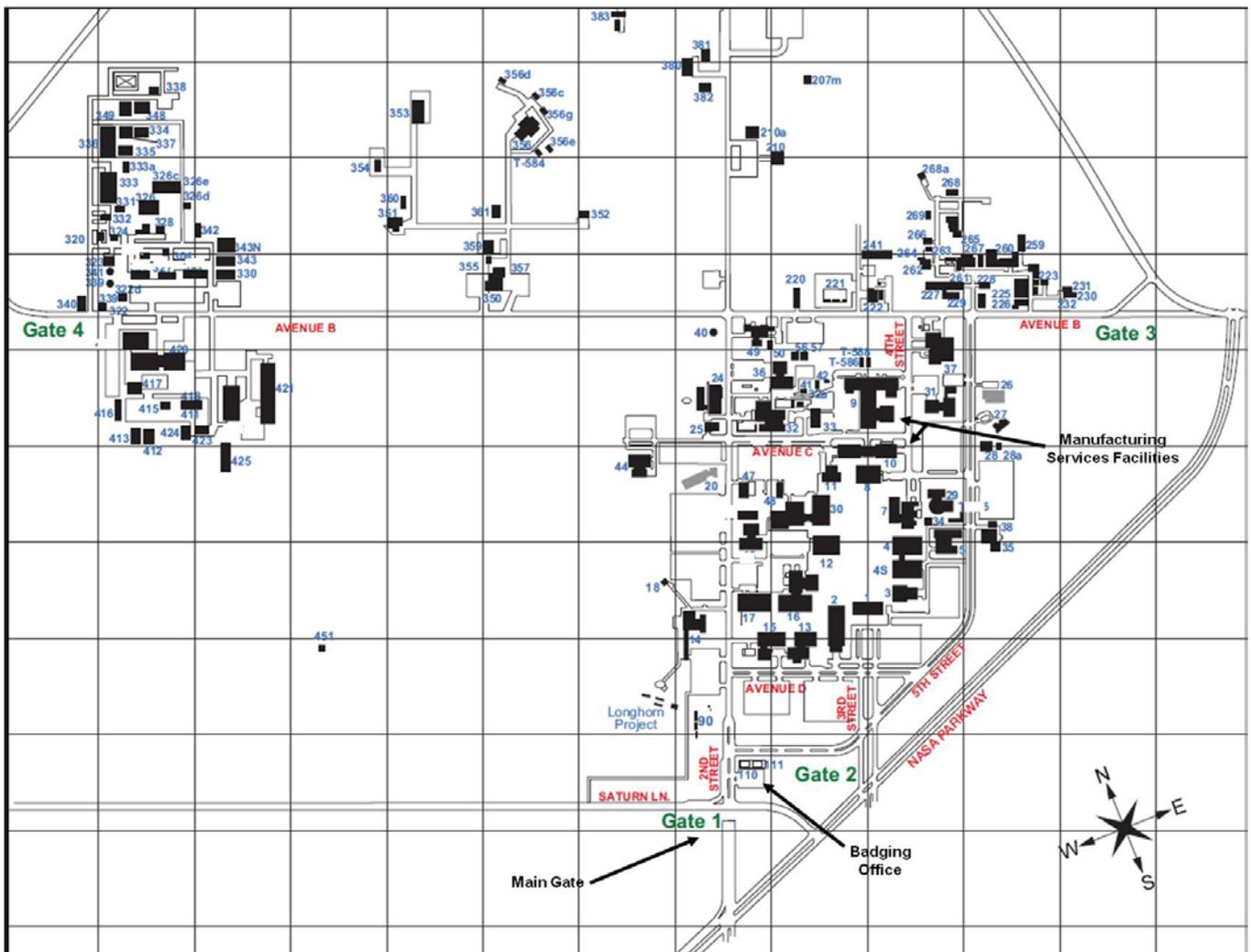
3.5.3 Customer Feedback

JSC encourages feedback from our customers. Evaluation of the services we provide enables continued improvement to our process. A Customer Feedback form is included in Appendix E. You are encouraged to complete the Customer Feedback form and return it to the Manufacturing POC, following receipt of your product. Your participation is greatly appreciated.

4.0 Facility Access

Identification badges are required for all persons requiring access to JSC. The Manufacturing POC or designee will initiate a badge request for all Requester personnel who require access to the Manufacturing Services facilities. Badge requests must be submitted at least 4 days prior to the visit to prevent badge processing delays. Badge requests for non-U.S. citizens may require a minimum of 30 business days to process. Requester personnel shall arrive at JSC Building 110 to pick up temporary identification badges. Visitors to JSC must show a current picture identification (valid driver's license, U.S. passport, government ID card).

The Manufacturing Services facilities are located in JSC Buildings 9 and 10. Visitors must be escorted at all times. Safety glasses are required at all times inside the high bays of Buildings 9 and 10. Safety glasses will be provided to visitors.



5.0 Roles and Responsibilities

Manufacturing POC – The primary interface between the facility and the Requester. The Manufacturing POC is responsible for developing the cost and schedule and the manufacturing plan and for resolving manufacturing issues.

Manufacturing Engineer – Provides technical support throughout the manufacturing process. The Manufacturing Engineer is available for design review, design for manufacturability, design for cost savings, and process expertise.

Requester – The client requesting manufacturing services. The Requester is responsible for defining the requirements and providing a Technical Expert.

Technical Expert – A representative of the Requester with thorough knowledge of the product design and requirements. The Technical Expert also is responsible for approving the manufacturing plan, processing redlines to drawings, and approving change requests.

Safety Engineer – Reviews the manufacturing plan to identify any additional hazards that could result in injury to facility personnel. The Safety Engineer also is responsible for providing the facility safety briefing to site visitors.

Quality Assurance – Responsible for product verification in accordance with the requirements defined in the manufacturing plan.

Responsibilities Matrix

Item	Requester	Facility
Manufacturing Request Worksheet	Create	Review
Cost and schedule	Approve	Create and sign off
Manufacturing plan (if requested)	Request, review, and approve	Create and sign off
Production		Fabricate and assemble product
Product verification	Define verification requirements	Perform product verifications
Change request	Request and approve	Sign off
Product delivery	Provide instruction	Execute per request

Acronyms

3D	Three-Dimensional
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CAD	Computer-Aided Design
CATIA	Computer-Aided Three-Dimensional Interactive Application
CMM	Coordinate Measuring Machine
CNC	Computer Numerical Control
CSM	Crew Service Module
DWG	Drawing
DXF	Drawing Exchange Format
EDM	Electrical Discharge Machine
EVA	Extravehicular Activity
FTP	File Transfer Protocol
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
JSC	Johnson Space Center
JWST	James Webb Space Telescope
MIG	Metal Inert Gas
MMOD	Micrometeoroids and Orbital Debris
NASA	National Aeronautics and Space Administration
NDT	Nondestructive Testing
POC	Point of Contact
R2	Robonaut 2
SEV	Space Exploration Vehicle
SMAW	Shielded Metal Arc Welding
STEP	Standard for Exchange of Product Model Data
TIFF	Tagged Image File Format
TIG	Tungsten Inert Gas

Appendices

- A. Design/Drawing Considerations
- B. Manufacturing Request Worksheet
- C. Available Facility Equipment
- D. Sample Products
- E. Customer Feedback

Appendix A Design/Drawing Considerations

General

- Dimension placement, line representation, and view selection should convey the design intent by showing important features and providing pertinent dimensions between critical features.
- Include the applicable military specifications and material specifications used in drawing notes to ensure feasibility, applicability, and completeness.
 - Provide alternate material choices and specifications wherever possible.
- Avoid unnecessarily tight dimensional constraints; perform appropriate tolerance analysis to reduce costs and the risk of scrapping parts.
- Drawings should be checked for the following:
 - Incorrectly specified tolerances, dimensions, and process specifications
 - Arbitrarily tight tolerances throughout the design
 - Dimensioning inconsistent with manufacturing methods
 - Incorrect or limiting material callouts or specifications
 - Unnecessary or limiting traceability requirements
- Consult with Manufacturing Engineering on any questions or issues you might have.

Welding

- Specify the weld filler material and specifications on the drawing.
- Avoid specifying welds in tight corners.
- Classify welds such that gradual straight lengths are used; avoid abrupt weld line changes.
- Specify intermittent welding whenever possible.
- Use the least exotic alloy possible, as allowed by the application.
- Design welds about the neutral axis of the component.
- Add detailed section views to the drawing as necessary to clearly specify the finished weld.

Machining

- Avoid thin unstable sections that would necessitate slow speeds and light cuts to minimize distortion.
- Avoid unnecessarily tight dimensional constraints; perform appropriate tolerance analysis to reduce costs and the risk of scrapping parts.
- Avoid unnecessarily precise surface finish callouts, which could require increased machining time or secondary operations, such as grinding.

- Use the same internal and external radius callout, as much as possible, to avoid unnecessary tool changes and increased machining time.
- Avoid small and deep internal radii.
- Avoid small fillet radii in deep pockets.

Metal Finishing

- Callout proper specifications for metal finishing processes on the drawing.
- Consider and allow for effects of the metal finishing process on the final dimensions of the part.
- Specify part dimensions on the drawing for before and after metal finishing processes, if needed.
- Specify on the drawing all surface preparation processes required for the metal finish process.
- Clearly indicate all areas to be blasted, etched, and masked; use a separate detail on the drawing, if possible.
- Clearly indicate on the drawing any processes that should not be performed on specific areas.

Mechanical Assembly

- Provide clear and concise assembly instructions on the drawing or in a separate procedure referenced on the drawing.
- Minimize the different types and sizes of fasteners used in an assembly.
- Specify proper torque values for fasteners.

Soft Goods

- On soft goods drawings, there should be a cross-section view for every type of seam configuration, with dimensions in the views.
- Stitch lines should be shown as dashed object lines (with a heavier line weight than hidden lines).
- Hidden lines should be shown at a different dash spacing and a lighter weight than object lines.
- Soft goods drawings use schematic representations of layers and components; fabric layer thicknesses and as-built seam thicknesses are not shown or depicted unless these are important to control.
- Drawings should show details such that assembly instructions are not needed.
- If assembly notes are needed, ensure that they are explicit and listed in sequence on the drawing.

File Formats

File formats that we can receive and send are listed in order of preference. Please note that you must understand the difference between Parts, Assemblies, and Drawings. We can accept drawings by fax for estimating cost and schedule, but we will need electronic copies prior to manufacturing. Models are preferred to CAD drawings.

Application	Parts		Assemblies		Drawings	
	Import	Export	Import	Export	Import	Export
Pro/E	X	X	X	X	X	X
STEP	X	X	X	X		
IGES	X	X	X	X		
Parasolid	X	X	X	X		
CATIA	X	X	X	X		
PDF		X		X		X
DXF/DWG	X				X	X
TIFF		X		X		X
JPEG		X		X		X

Notes:

1. If you send Pro/E drawings or assemblies, you must also send the associated part files.
2. The size limit for e-mailed files is 10 MB. Split files into multiple e-mails and/or ZIP the files.
3. If you send CAD data that can be imported into Pro/E, we will use it. If it is incorrect, your estimate could also be incorrect. If we see obvious problems between hardcopies and the CAD data, we will contact you for clarification.
4. Please contact the Manufacturing POC for instructions for FTP. The Manufacturing POC will send you an invitation to the NASA FTP site so that you can upload your files directly.

Appendix B Manufacturing Request Worksheet

Requester Information

Technical Point of Contact:	Contact Information (Phone, E-mail, Address):
Backup Point of Contact	Contact Information (Phone, E-mail, Address):

Job Request

Scope of Work:	
Target Delivery Date:	Critical Delivery Date:
Special Instructions (Actions that should or should not be done; e.g., Make part xxx only, customer will assemble):	

Customer-Supplied Material:

Product Information

Qty:	Product Name:			
Drawing Package:	E-mail <input type="checkbox"/>	FTP <input type="checkbox"/>	Fax <input type="checkbox"/>	Mail (CD/DVD) <input type="checkbox"/>
Drawing/Model Format (Accepted Formats Included)	Pro/ENGINEER <input type="checkbox"/>	STEP <input type="checkbox"/>	Parasolid <input type="checkbox"/>	
	DXF/DWG <input type="checkbox"/>	PDF <input type="checkbox"/>	CATIA Graphics <input type="checkbox"/>	
Comments:				

We encourage you to submit electronic copies of your drawings. We can accept files through an FTP site, by e-mail, or via standard mail. Contact the Manufacturing POC to discuss the best method to submit your drawings/models.

Packaging/Shipping Instructions

Delivery or Pickup:	Delivery Address:
Special Packaging Instructions:	

Additional Services

Cleaning (Y/N):	Comments (Cleanliness level, specific parts):
Manufacturing Data Package (Y/N):	Comments (Traceability, required data):
Manufacturing Engineering (Y/N):	Comments (design review, design for cost savings, design for manufacturability):
Dimensional Inspection (Y/N):	Comments:
As-Built Prints (Y/N):	Comments:
Weld Inspection (Y/N):	Comments (Type):
Weld Process/ Welder Certifications (Y/N):	Comments:
Nondestructive Testing (Y/N):	Comments (Type of NDT):
Progress Reports (Y/N):	Comments (frequency, information):
Test Coupons (Y/N):	Comments:
Materials Certification (Y/N):	Comments:

Appendix C Available Facility Equipment

Mills

Qty	Type	Work Envelope
1	Bridge Mill 5-Axis CNC Machining Center	157"(X) x 98"(Y) x 39"(Z)
1	Vertical 5-Axis CNC Machining Center	64"(X) x 32"(Y) x 24"(Z)
6	Vertical 3- to 4-Axis CNC Machining Center	30"(X) x 24"(Y) x 24"(Z)
4	Vertical 3- to 4-Axis CNC Machining Center	50"(X) x 30"(Y) x 24"(Z)
1	Vertical 3- to 4-Axis CNC Machining Center	80"(X) x 36"(Y) x 24"(Z)
1	Vertical 4-Axis CNC Knee Mill	31"(X) x 14"(Y) x 5"(Z)
6	Vertical 3-Axis CNC Knee Mill	24" x 14"
1	Vertical 3-Axis CNC Machining Center	100"(X) x 30"(Y) x 24"(Z)
1	Bridge Mill 3-Axis CNC Machining Center	120"(X) x 60"(Y) x 24"(Z)
1	Horizontal 5-Axis CNC Machining Center	
5+	Vertical Mill	
1	Horizontal Mill	48"(X) x 48"(Y) x 60"(Z)

Lathes

Qty	Type	Work Envelope
1	CNC Lathe	5" Swing x 13" Length
1	CNC Lathe	17" Swing x 20" Length
1	CNC Turn Lathe/ Mill, 3-Axis	10.5" Swing x 21" Length
1	CNC Turn Lathe/ Mill, 4-Axis	22" Swing x 52" Length
1	CNC Lathe	15" Swing x 40" Length
1	CNC Turn Lathe/ Mill, 4-Axis	
1	Manual Lathe	13" Swing x 36" Length
2	Manual Lathe	8" Swing x 18" Length
1	Manual Lathe	25" Swing Length
3	Manual Lathe	Varies
3	Manual Lathe	10" Swing x 20" Length

EDM

Qty	Type	Work Envelope
1	CNC 4-Axis Wire EDM	33"(X) x 25"(Y) x 11"(Z)
1	CNC 4-Axis Wire EDM	25"(X) x 29"(Y) x 10"(Z)
1	CNC Wire EDM	39"(X) x 47"(Y) x 13"(Z)

Heat Treating

Qty	Type	Work Envelope
1	Heat Treat Oven – Recirculating Air	72"(d) x 48"(w) x 28"(h)
1	Heat Treat Oven – Recirculating Air	24"(d) x 34"(w) x 24"(h)
1	Heat Treat Furnace – Air	20"(d) x 15"(w) x 12"(h)
1	Heat Treat Oven – Air	14"(d) x 8"(w) x 8"(h)

Sheet Metal

Qty	Type	Work Envelope
2	Water Knife	60" x 144" and 60" x 87"
1	Brake	120" x 48" LVD
1	Brake	72" x 48" Stroke
1	Shear	48" x 144"
1	Shear	48" x 144"
1	Drill Press	48" x 72"
1	Iron Worker	Up to 18" Deep
2	Saw	144" Length

Specialized Equipment

Qty	Type	Work Envelope	Notes
1	Additive Manufacturing Machine	300 mm ³	3 axes standard: XY linear/Z gantry motion ± 0.25 mm positional accuracy Gas purification O ² < 10 ppm
1	Salt Fog Chamber	72" x 42" x 42"	Temperatures: Ambient to 120 °F Humidity: Ambient to 100%
1	Friction Stir Welder	25" x 40" x 80"	5 axes, 7 degrees of freedom Ferrous and nonferrous metals High strength, low residual stress welds
2	Autoclaves	7' x 16' and 2' x 4'	Curing epoxies and resins Temperatures up to 600 °F

Surface Preparation and Finishing

Qty	Type	Work Envelope	Process Usage	Notes
1	Sodium Metalicate and Sodium Xylenesulfonate	60"(w) x 24"(d) x 36"(h)	Removes grease and oil from part surfaces	Allows a more uniform etch of part surfaces
1	Sodium Hydroxide (NaOH)	60"(w) x 24"(d) x 36"(h)	Removes foreign particles chemically	Will decrease a part's volume by approximately 0.001 inch, depending on time in acid bath
1	Nitric and Hydrofluoric Acid	60"(w) x 24"(d) x 36"(h)	Deoxidation of part	
1	Plastic Bead Media	48"(w) x 36"(d) x 36"(h)	Stripping of paint and (some) corrosion	Will not damage part/ material surface
1	Aluminum Oxide Media (Standard grit is 220)	36"(w) x 24"(d) x 23"(h)	Remove corrosion, strip paint, and prepare surface for coating	Standard grit is 220; change-out to 120 or 54 requires extra costs to project
1	Glass Bead Media	30"(w) x 30"(d) x 30"(h)	Remove rust, or prepare surface for coating	
2	Paint Booths	256 ft ² 50 ft ²	Corrosion protection with paints, lacquers, and lubricants	Polythanes, epoxy, latex, Tiolube, 3M products, Dow Corning products, dry film lubricants

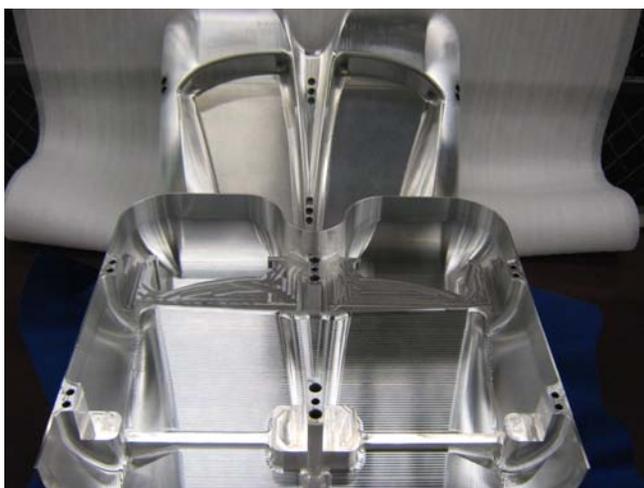
Appendix D Sample Products



Robonaut 2 Finger Actuator Mount
CNC Lathe, Mill, 4-Axis Mill
Aluminum from 4" Rod
Parts Made from Model



Robonaut 2 (R2)



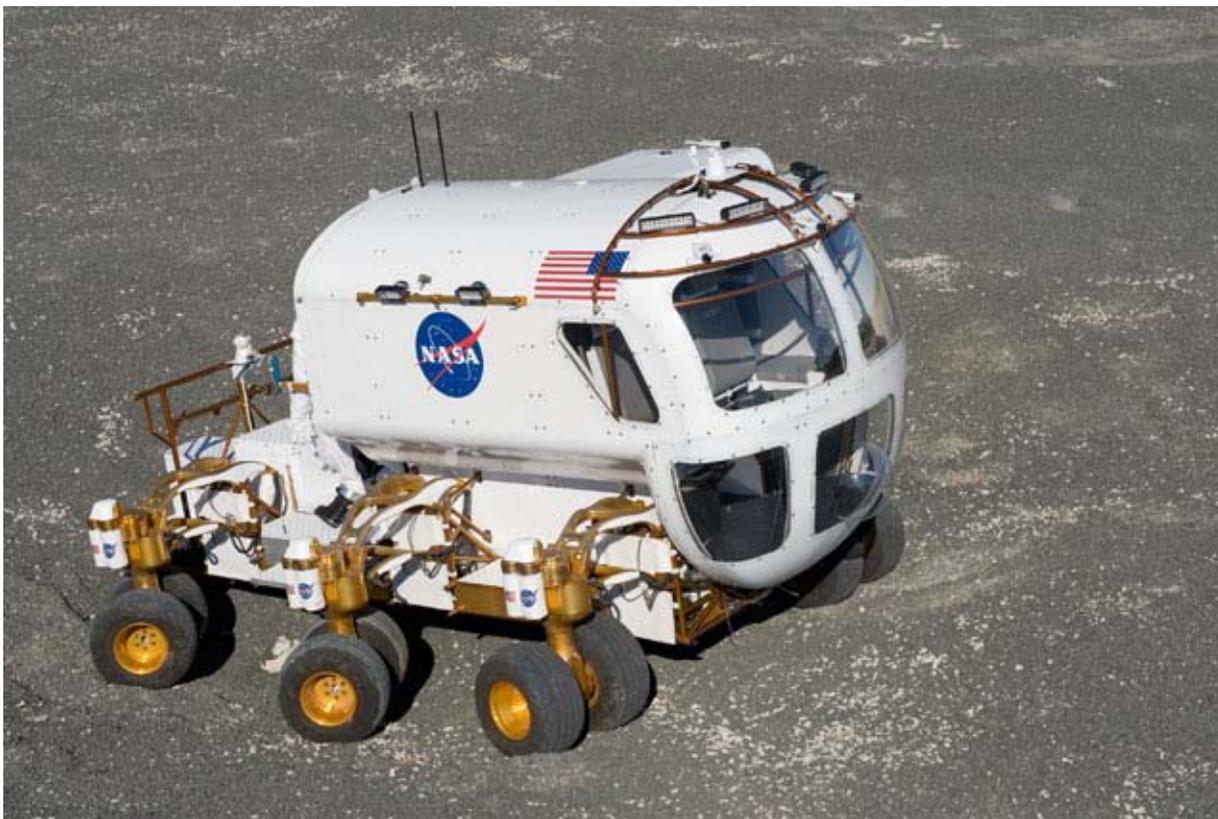
Robonaut 2 Backpack Panel
Lightweight, 0.080" Walls, 5 lb
Stock size: 20" x 15.25" x 25.4"



Various R2 Parts
Parts Made on Lathe and Mill



Space Exploration Vehicle (SEV)
All Parts Made from Models



Space Exploration Vehicle



Crew Service Module (CSM) Mockup Facility



James Webb Space Telescope (JWST) Test Floor Assembly



Double Coldbag



Inflatable Habitat



Attenuation Tube Assembly



Morpheus Lander Mockup

Appendix E Customer Feedback

MANUFACTURING CUSTOMER FEEDBACK						
Product:				Target Delivery Date:		
Manufacturing POC:				Delivery Date:		
MANUFACTURING POC:	SCORE (Check or Click on Box)					
	1	2	3	4	5	N/A
1. Did the Manufacturing POC clearly communicate how your project would be processed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Did the Manufacturing POC provide a cost competitive ROM estimate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Did the Manufacturing POC provide everything that was expected?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Do you feel that the Manufacturing POC has provided you a valuable service?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PLANNING:						
5. Was your product planned and scheduled to meet your needs?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Were issues or concerns that affected your project communicated clearly?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Do you feel that the Planning Department has provided you a valuable service?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PRODUCT:						
8. Did we provide a quality product?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Did we provide a cost competitive product?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Did we provide on-time delivery?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
GENERAL:						
11. Was the order entry process clearly understood?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Was the order entry process easy to use?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Do you feel that we provide a one-stop shop?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Note: We are concerned and interested in your comments and would like an opportunity to improve our services.						
Comments/Suggestions for Improvement:						
Customer Name and Organization:						
Return to: Manufacturing POC						