

Modifications of Hinge Mechanisms for the Mobile Launcher

Jacob D. Ganzak

NASA John F. Kennedy Space Center

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Final Technical Report for Spring 2018 NASA Internship Modifications of Hinge Mechanisms for the Mobile Launcher

Jacob D. Ganzak *

*NASA John F. Kennedy Space Center, FL 32899
Western Michigan University, Kalamazoo, MI 49008*

The further development and modifications made towards the integration of the upper and lower hinge assemblies for the Exploration Upper Stage umbilical are presented. Investigative work is included to show the process of applying updated NASA Standards within component and assembly drawings for selected manufacturers. Component modifications with the addition of drawings are created to precisely display part geometries and geometric tolerances, along with proper methods of fabrication. Comparison of newly updated components with original Apollo era components is essential to correctly model the part characteristics and parameters, i.e. mass properties, material selection, weldments, and tolerances. 3-Dimensional modeling software is used to demonstrate the necessary improvements. In order to share and corroborate these changes, a document management system is used to store the various components and associated drawings. These efforts will contribute towards the Mobile Launcher for Exploration Mission 2 to provide proper rotation of the Exploration Upper Stage umbilical, necessary for providing cryogenic fill and drain capabilities.

Nomenclature

<i>3D</i>	=	3-Dimensional
<i>CAD</i>	=	Computer-Aided Design
<i>CLV</i>	=	Crew Launch Vehicle
<i>EM</i>	=	Exploration Mission
<i>EUS</i>	=	Exploration Upper Stage
<i>F</i>	=	Maximum diameter of fastener (MMC limit)
<i>GD&T</i>	=	Geometric Dimensioning and Tolerancing
<i>H</i>	=	Minimum diameter of clearance hole (MMC limit)
<i>ICPSU</i>	=	Interim Cryogenic Propulsion Stage Umbilical
<i>KSC</i>	=	Kennedy Space Center
<i>LAS</i>	=	Launch Abort System
<i>LMC</i>	=	Least Material Condition
<i>ML</i>	=	Mobile Launcher
<i>MMC</i>	=	Maximum Material Condition
<i>NASA</i>	=	National Aeronautics and Space Administration
<i>RFQ</i>	=	Requests for Quotation
<i>SLS</i>	=	Space Launch System
<i>SOW</i>	=	Statement of Work
<i>T</i>	=	Positional tolerance diameter
<i>TOSC</i>	=	Test Operation and Support Contract

I. Introduction

Dating back to the start of the Apollo Saturn V program in the 1960's, NASA's Kennedy Space Center (KSC) has used launch towers to support rocket stability and power supply for manned and unmanned spaceflight. In order to stabilize rockets to their designated launch tower, a series of truss structures, or vehicle stabilizer arms, branch out from the tower to grasp the rocket in several vertical positions. Umbilical arms provide sufficient power, purge and vent control, and cryogenic fill and drain capabilities to the rocket prior to launch. The upcoming Space Launch System (SLS) assembly will utilize a Mobile Launcher (ML) that consists of the launch tower attached to the launch platform, making it one entity. The SLS will be supporting the next generation of deep space rocketry to promote manned spaceflight for decades to come. Exploration Missions 1 and 2 (EM-1 unmanned and EM-2 manned, respectively) will be serving as the first deep space campaign; EM-1 is predicated to launch in late 2019 and EM-2 is predicted to launch in 2022. Upon integration of the ML, a proposed structural modification design contract has been established to convert the Crew Launch Vehicle (CLV) ML to be used for the SLS launch vehicle⁶. Because EM-1's objective involves a payload only (unmanned), the SLS design for EM-2 will require modifications to support astronauts. The addition of the crew capsule and Launch Abort System (LAS) will require the ML to be modified to support this forty-foot vertical extension.

The main focus of this project is to assist the Launch Accessories Branch in the hinge modifications to support proper rotation of the Exploration Upper Stage (EUS) umbilical at EM-2 rocket liftoff. The EUS serves as a vital commodity umbilical derived from the Interim Cryogenic Propulsion Stage Umbilical (ICPSU), controlling cryogenic filling and draining to the SLS upper stage¹. Because of their rigidity and robust integrity, these hinge mechanisms were originally designed in the early 1960's to support Apollo Program launch tower rocketry, i.e. the Saturn V. NASA is continuing to reuse the Apollo era (original) hinge designs to support not only the EUS, but multiple umbilicals for SLS with the exception of modifying chemical coatings, weldments, protective finishes, and inspections on the hinges themselves. Shown in Figure 1 are two mounted upper hinges on the ML. It is important to note that the current configuration of the ML in this figure is for EM-1, and therefore does not display the EUS umbilical. This figure is to assist the reader with orientation of the hinges on the ML. The objective of this paper is to describe the contributions made towards the hinge assembly modifications for the EUS umbilical.



Figure 1. Two upper hinges mounted on ML.

II. Document and Company Search

A. Technical Standards

The newly modified hinge mechanism components are highly dependent on their original design - this includes all the associated notes such as the type of material, proper identification marking, heat treatments, and protective coatings. The original design drawings are accessible through the NASA Technical Library. Specific numbered drawings were subjected to modifications. NASA launch operations at KSC decided to create new drawings

*Structural and Design Engineer, Launch Accessories Branch, National Aeronautics and Space Administration
Kennedy Space Center SR 405, FL 32899, Western Michigan University 1903 W. Michigan Ave, MI 49008.

derived from the Apollo era Marshall drawings to use for the Kennedy documentation system since KSC now has authority over launch procedures and equipment.

First, an original drawing was selected from the existing hinge assembly and searched in KSC's technical database to update the associated notes. Secondly, after reviewing the drawing, the referred standard documents in the notes section needed to be checked for validity. Once these documents were obtained and compared to the KSC Standard Drawing Notes ⁵, a new set of notes for each part was temporarily created on a Word Document to be later applied to the newly created drawing. This investigative work lasted approximately four weeks in order to search for all the discontinued standards and incorporate the new KSC Standard Drawing Notes. It is important to note that there are approximately 80 parts for both the upper and lower hinges that are subjected to modifications. Of that 80, half are duplicate parts and therefore will be used on both upper and lower hinges.

B. Company Contacts

Business relations is a crucial element in the process of vendor selection for NASA. It allows NASA to stay in contact with international businesses to maintain high standard products and technology to be fabricated and implemented. Being a budget sensitive agency, NASA considers all contracting offers when selecting component fabrication, thus considering the quotation (prices) of the offer. Additionally, knowing the availability of these products assists the procurement team in finalizing project costs and delivery time.

Located within several original drawing notes, a recommended vendor is included for future use of certain components. This raised an issue of company existence since the original drawings were designed and fabricated in the early 1960's. Consequently, many of the recommended vendors and contracting companies of the hinge components are either out of business or were bought out by a larger corporation. Part of the first four weeks of investigative work included contacting these vendors to determine whether they 1) still existed, and 2) were capable of fabricating the same component with the applied drawing updates and standards.

III. Component and Drawing Development

A. Component Modification

The primary objective of creating new drawings for the hinge assemblies is to have accessibility to these drawings in the external document system which allows personnel to view traceability, changes, related objects, and specifications of each component. The next step in the process of creating the new drawing was to obtain the preexisting 3D part in the Computer-Aided Design drawing package. However, these parts were modeled to represent a draft assembly of the hinges to use for higher assemblies and therefore did not include all features and parameters. By utilizing the original drawings in NASA's technical documentation library, the preexisting parts were copied as a new component and the missing features were added to the model. The following list includes commonly missed features that were on the original drawings but were not included on the model:

- Rounding features
- Datum planes and axes
- Through holes
- Creation of separate components (for assemblies)

Subsequently adding the missing features, the part parameters were compared with the original drawings. Part parameters are vital in CAD because they allow the manufacturer to view part specifications that determine its properties for accurate fabrication. The following list includes commonly missed parameters that were on the original drawings but were not included in the model:

- Final protective finish
- Heat treatment
- Stock size

1) Creation of Separate Components

For a particular original part, the preexisting 3D model was incorrect since it was modeled as one part. In the original drawing, the part consisted of two stainless steel plates that were welded together after bending to shape. This issue was resolved by redesigning the two plates separately and creating an assembly file. This assembly model is important once the drawing is created because the generated parts list will display the component specifications for each part in the assembly.

B. Drawing Creation/Modification

In 3D drawing package, drawings are dependent on its created model. It is crucial to show the necessary dimensions, datums, and orientations in the model. As a result, this allows the draftsmen to make the associated Geometric Dimensioning and Tolerancing (GD&T) in the model. GD&T serves as a standard tolerancing system for manufacturers to accurately fabricate components to the specific tolerance/dimension. GD&T follows a datum reference frame that consists of a three-plane concept. By following this method, engineers are able to use perpendicular features of a part to properly place three datum references to control its free movement in space. Figure 2 shows a part that is constrained by three sides and therefore restricting the three degrees of rotation. After the new part is modified, a new drawing is subsequently created. It is important to make the new drawings exactly as its parent drawing. However, because these original drawings date back to the early 1960's, several drawing features were missing or out-of-date when compared to modern day drawing standards. The following list includes commonly missed drawing features that needed to apply to the newly created drawings:

- Datum planes and axes symbols
- Material conditions
- Primary, secondary, and tertiary datum references
- Dimensioning symbols
- Clearance hole/through-hole GD&T

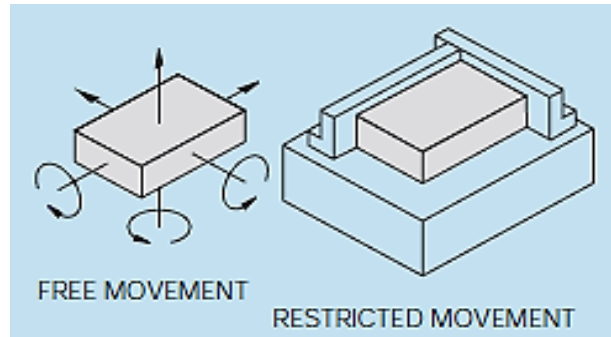


Figure 2. Three-plane concept to restrict part rotation.

1) Clearance Hole/Through-Hole GD&T

This section includes an example of adding these drawing features is the modification of clearance hole GD&T to a part. In the original drawing, there were no created datum planes to reference for through-hole location. In order to specify the precision of a hole's location, the draftsmen typically needs three datum planes to determine the hole's center axis tolerance that it needs to fit inside. Additionally, the draftsmen needs to determine whether the condition of the component is maximum or least material - Maximum Material Condition (MMC) is where a feature of size contains the maximum amount of material within the stated limits of size and Least Material Condition (LMC) is where a feature of size contains the least amount of material within the stated limits of size ³. For the retainer plate, it has a MMC and therefore the through-holes' positional tolerance diameter (T) shall be calculated with the fixed-fastener case. The fixed-fastener case states that the fastener is restrained in its position due to a tapped hole and therefore does not contain a nut.

First, in order to calculate T , the following formula applies:

$$H = F + 2T \quad (1)$$

or

$$T = \frac{H-F}{2} \quad (2)$$

where F is the maximum diameter of the fastener and H is the minimum diameter of the clearance hole. Applying equations (1) and (2) gives the positional tolerance diameter for that clearance hole. This method is applied to all

fixed-fastener through-holes for the modified components to improve GD&T for manufacturers². Once T is calculated, the geometric tolerance annotation is added to the drawing.

IV. Final Remarks

The work stated throughout this paper was performed in the time period of 16 January, 2018 to 4 May, 2018. In that time, KSC launch operations has proposed the possibility of constructing a new Mobile Launcher for the Space Launch System instead of continuing to convert the existing CLV mobile launcher. In regards to work stated in this paper, it will stay valid since its purpose is affecting the EUS umbilical and similarly derived umbilicals. However, readers should be aware of this potential change since other work related to the design of the mobile launcher may be affected and could impact the constraints of launch hardware and equipment.

V. Conclusion and Future Work

NASA's decision to reuse the Apollo era upper and lower hinge assemblies has started the development of component and drawing modifications for the EUS umbilical to support the NASA Launch Accessories Branch. This work will contribute to the ML conversion for EM-2 SLS. By investigating the original hinge component drawings, several technical standards were found to be discontinued because of outdated procedures - identification markings, protective coatings, paint coatings, material cleaning methods, surfaces finishes, and heat treatments. The updated and republished versions of the associated standards were selected and assimilated on the newly created drawings. A good portion of the time was spent gathering updated technical documents since they were further validated by the KSC drawing standards document. This document contains republished standards that are referenced in modern day drawing standard notes to allow accurate and efficient fabrication for manufacturers. In order to apply these notes to a new drawing, the preexisting model was copied and examined for missing features. This was performed by comparing the model with the original drawings which represent the Apollo era hinge mechanisms and components. The Apollo era hinge drawings were accessed through an archival search engine capable of searching for NASA drawings.

Vendor and contractor existence was also investigated to assist the procurement team in Requests for Quotation (RFQs). This will allow the procurement team to determine if the vendor is still able to fabricate the component and if so, determine the estimated delivery date.

By creating new and updated drawings, this allows NASA/contractor personnel to access these drawings on a data management system controlling the traceability, changes, object relation, and specifications of every created part. In order to create a new part from the original drawing, the preexisting model was extracted from the 3D modeling package and saved as a new copy. The preexisting models lacked sufficient features due to their initial purpose to represent draft assemblies for next higher assemblies. Missing model features included rounding features, datum planes and axes, through-holes, and creation of separate components. The new copied model was generated with the applied missing features, derived from the original drawing. Part specific parameters were also applied such as final protective coatings, heat treatments, and stock sizes. These added features and parameters are necessary for accurate manufacturer fabrication.

CAD drawings are dependent on their associated model. Therefore, all datum planes, dimensions, and orientations should be included in the file. This allows the draftsmen to create GD&T for model features to select the degree of precision for the manufacturer. GD&T follows a three plane concept to restrict a part from moving in 3D space. GD&T was one of several missing features in the original drawings (other missing features include datum planes and axes symbols, material conditions, primary, secondary, and tertiary datum references, and dimensioning symbols). Standards are referenced throughout the creation of new drawings to give positional tolerance to clearance holes. Positional tolerance supplies a manufacturer with the center axis tolerance of a hole that it must fit inside when drilled. On the hinge assembly, many of the fasteners are fixed-fasteners in which the fastener does not require a nut to restrain it. Instead, they are restrained by cosmetic threading and tapped holes. To calculate the positional tolerance diameter for the fixed-fastener case, formulas (1) and (2) were used with the designated H and F (minimum diameter of hole and maximum diameter of fastener, respectively, with a MMC).

Upon displaying GD&T annotations, the following symbols/notes need to apply within the drawing: geometric tolerance symbol, calculated tolerance, material condition, and the referenced datums. It is important to show the referenced datums in the drawing itself to provide as a visual aid.

Future work for this project has been notified by the Test Operations and Support Contract (TOSC) to assist in the completion of modeling and drawing modifications for the EUS hinges. Before the projected date to release the hinge assembly components for fabrication, a critical design review, following a Statement of Work (SOW), will take place to finalize component design and stress data and resolve any altercations that may affect the NASA Project Life Cycle ⁴.

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