Realization of astrosat Model with Fused Deposition Modelling

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Abstract—*The current work focuses on the challenges faced while realizing the 3D Model of ASTROSAT using Fused Deposition Modelling (FDM) - A material extrusion based additive manufacturing technology. Initially, the entire assembly of the ASTROSAT was studied and modified appropriately to suit the demonstration model. The modified assembly was scaled down to 1:6 scale. The scaled down model was then re-modified at the local subsystems (or individual component) level, according to the manufacturability through FDM and this was the major challenge faced due to constraint on minimum printable feature size. All the subsystems or individual components were converted to STL format and were printed on FORTUS 400MC of Stratasys. Thus obtained 3D printed parts were assembled as per the assembly drawing. It was found that, the FDM technology and Additive Manufacturing technology as a whole, is very useful in realizing the complicated demonstration modelsin a very short duration, without compromising the prominent engineering features.*

Keywords— ASTROSAT, Additive Manufacturing, Fused Deposition Modelling, ABS, Design for Additive manufacturing.

I. INTRODUCTION

ASTROSAT is one of the prestigious projects of ISRO and it attracted the attention of various scientific communities and enthusiasts. The spacecraft houses several co-aligned instruments covering the desired multi spectral bands so that simultaneous astronomical observations are possible.

The prominent payloads of ASTROSAT include UVIT (Ultraviolet Imaging Telescope), LAXPC (Large Area X-ray Proportional Counter), SXT (Soft X-ray Telescope), CZTI (Cadmium Zinc Telluride Imager) and SSM (Scanning Sky Monitor). UVIT is capable of observing the sky in the visible, near Ultraviolet and far Ultraviolet regions of the electromagnetic spectrum. The two telescopes present in the UVIT payload are designed to achieve an excellent image resolution and to have a large field of view.LAXPC was designed to study the variations in the emissions of X-rays from sources like X-ray binaries, active galactic nuclei and other cosmic sources. SXT payload can study X-rays coming from the distant celestial bodies which vary with time. CZTI payload can sense high energy X-rays. SSM is intended to scan the sky for long term monitoring of bright X-ray sources[1]. The 3D CAD Model of ASTROSAT assembly is shown in Fig 1.

During clean room activities and post launch, demonstration of various prominent payloads of the satellite like, SSM, UVIT, SXT etc., is not possible due to the extreme cleanliness demands of the different payloads. Hence a demonstration model which can effectively demonstrate the engineering features of prominent payloads is required. The demonstration models of various satellites have been manufactured using traditional/conventional manufacturing techniques like sheet metal forming, machining, turning etc. But these models were unable to reproduce the intricate engineering features of the satellites exactly. P. Rochus et al.[2], have discussed the possibility of using additive manufacturing technology for realizing the prototypes related to aerospace industry. Additive manufacturing according to ASTM is “A process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.”[3]

In this work an attempt has been made to realize the complex 3D Model of the ASTROSAT using FDM with ABS thermoplastic.

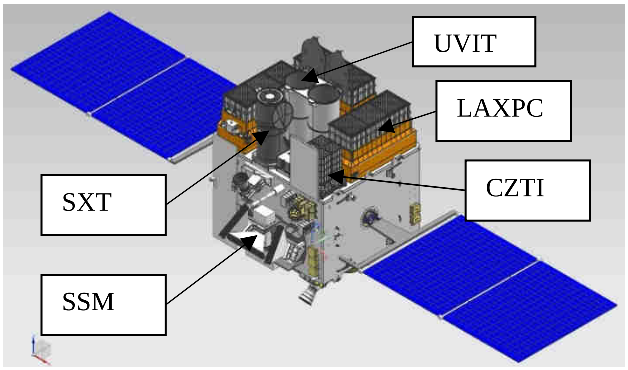

Fig 1: ASTROSAT Model with prominent payloads

II. FUNCTIONING MECHANISMS TO BE REALIZED

The 3D printed model should have functioning mechanisms for following payloads/assemblies:

UVIT:

The top cover of the UVIT payload should have a provision to open upto an angle of 95° as shown in Fig 2.

SXT:

The covers of SXT payloads should have a provision to open upto an angle of 256° as shown in Fig 2.

SSM:

The rotating table on which SSM is mounted should have a provision to rotate from 3° to 357° with constriction of motion as shown in Fig 3.

Solar Panel Assembly:

There should be a provision for the folding of individual solar panels at hinges and also rotation of entire panel at interface bracket. The rotation of the solar panel is with respect to panels of spacecraft.

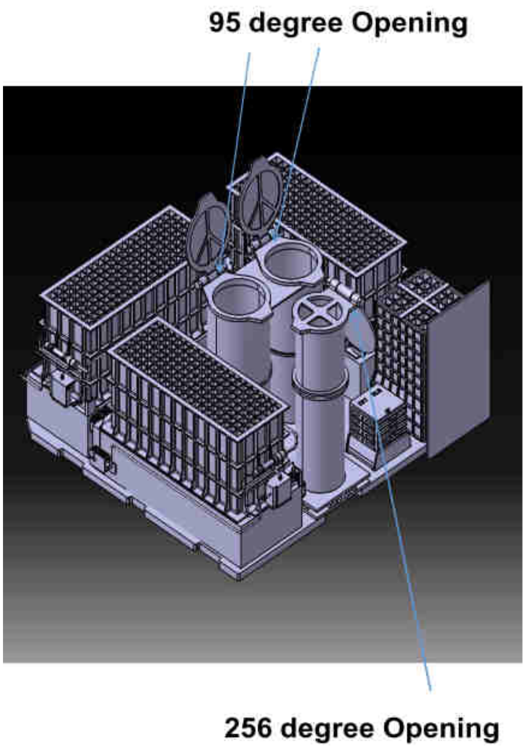

Fig .2: UVIT and SXT cover opening

III. MODELLING OF SCALED DOWN ASTROSATASSEMBLY

It was decided to print the ASTROSAT model in 1:6 scale based on the actual size of the ASTROSAT Satellite. This scale was fixed based on the minimum printable size of FDM. The entire CAD modeling was done using NX CAD software. It took two man months

(a)

(b)

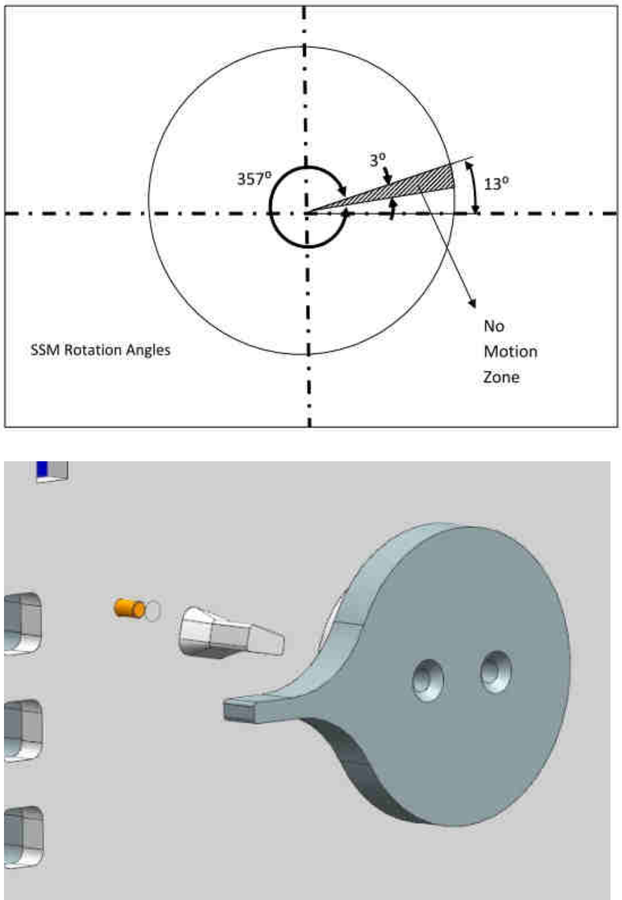

Fig. 3: SSM Rotary mechanism. (a) Rotation Constraint (b) Design in scaled down model

for scaling downthe CAD model of ASTROSAT to suit for FDM.

a. Major Challenges faced in preparation of scaled down CAD model

i. Handling Small size features

There are many components in satellite where the ratio of largest dimension to smallest dimension is very high and even goes upto 80-85. This posed a big challenge when handling a dimensions lesser than 9 mm. Additive manufacturing technology has a constraint on minimum printable size and this is approximately equal to 1.5 mm for FDM for a reasonable size of feature to withstand static load with certain factor of safety. When the complete model of ASTROSAT Satellite was scaled down to 1:6 scale, there were many features which were measuring less than 1.5 mm and even the features sizes upto 0.1 mm were present at several places. The major challenge was to make such features printable.

The local scaling of features at the component level was done after the global scaling of 1:6 at assembly level. While doing so, feature sizes were increased to keep atleast 1.5 mm. In doing so at many places, either the different features were getting merged or the aspect ratio (look & feel) as compared to actual satellite was deviating two much. In such cases features were reshaped and it was tried to maximum extent to give the same look and feel as the original satellite. Fig 4 shows the way, SADA (Solar Array Deployment Assembly) mechanism is modified without affecting its functionality and making it 3D printable.

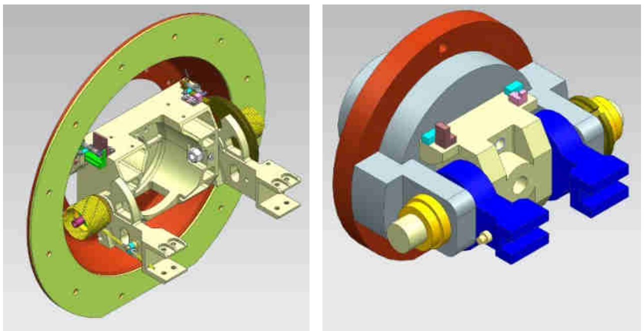

Fig: SADA mechanism in original (left) and scaled down (right) model of ASTROSAT

b. Solid Geometry available in neutral CAD formats

Most of the parts of ASTROSAT CAD model were available in neutral CAD formats like STEP or IGES primarily due to two reasons. Many payloads for ASTROSAT were realized in collaboration with external agencies. The data supplied by them was in neutral formats due to usage of different CAD softwares. The second reason was due to change of CAD platform at ISRO Satellite Centre. Initially ASTROSAT Satellite was modeled in MDT 2007 software which was the major 3D CAD tool being used at ISAC. Later on in year 2007 ISAC migrated to NX CAD software due to limitations of MDT and advantages of NX. ASTROSAT was also migrated to NX as MDT was not considered for the large assembly of ASTROSAT.

When a neutral format geometry was imported in CAD software, there was no feature tree available for the component. Due to the restriction on the minimum feature size, almost each and every component required modification at local feature level. The work required was almost equivalent to creating the entire Satellite assembly from the scratch. However to meet this challenge, synchronous technology in NX was used. Synchronous technology offers an interactive method of editing a geometry for which no feature history is available. Through synchronous technology features of component were edited locally and the components were made fit for 3D printing. This method saved a lot of time and manpower.

i. Components as Surface Models

As mentioned in 4.1.2, many geometries were available in IGES. When such geometries are imported in CAD software, they are imported as surfaces. Through 3D printing, surface models cannot be printed as they have no thickness. Converting these surface models to solid models was a big challenge as the geometries involved were quite complex. Due to complexity of the geometry, CAD software was not able to convert surface models to solid models automatically although there were several commands in CAD software.

To solve this issue, a mixed approach was adopted. Surface models were converted to solid models by selectively converting the features to solid by using normal features like extrude, revolve etc. and by the use of synchronous technology. Some features were recreated based on the geometry of original CAD model and thereby the scaled down solid model of geometries available as surface models, was created.

ii. Strength of Scaled down components

Most of the mechanisms on ASTROSAT model were designed to be in stowed mode during launch and later on to be deployed in orbit. In deployed conditions these mechanism work in 'Zero g' environment. On the other hand, the simulated mechanism on the prototype model will be under Earth's Gravitational pull in deployed condition. Hence these mechanismswereredesigned to be sufficiently strong. The load bearing components were redesigned, re-shaped and scaled up in order to have sufficient strength. Also long rods were designed to give support to solar panels as shown in Fig 5.

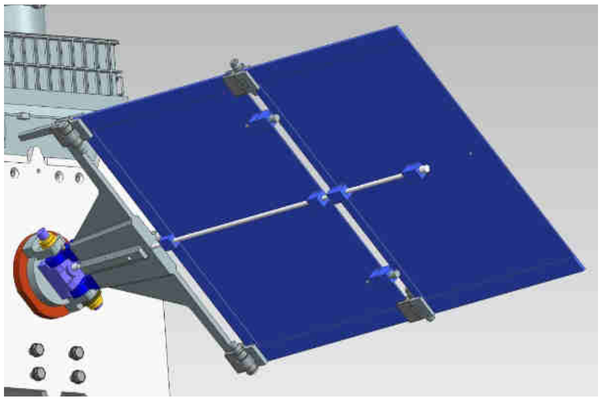

Fig. 5: Solar panel in deployed condition

iii. Stowed and Deployed Configurations

The mechanism on satellite are kept in stowed or deployed mode, through the use of pyro devices or motor drives or springs. On the prototype model, it was not considered to make these arrangements. Hence on the prototype models the deployed and stowed configurations were achieved by the use of pins and, nut and bolts as shown in Fig 6.

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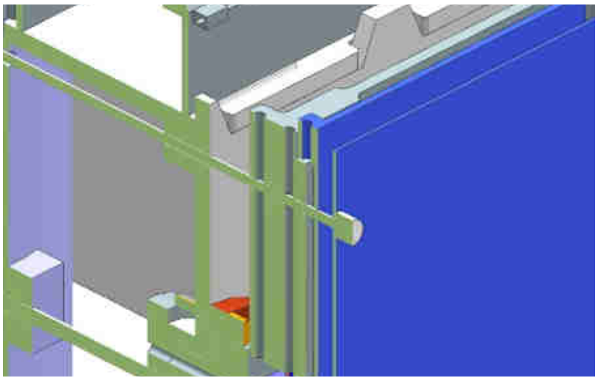

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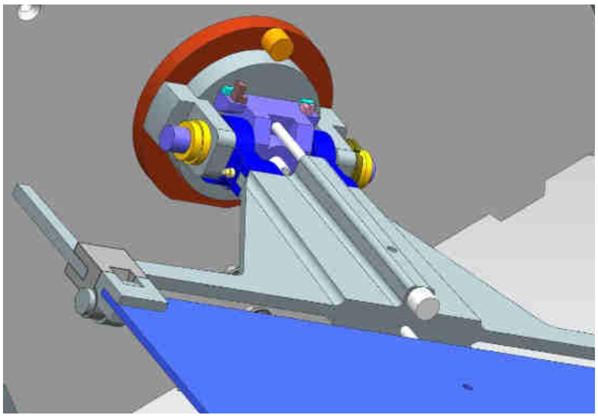

Fig. 6: SADA mechanism (a) Cross section view in stowed condition (b) In deployed condition

IV. FUSED DEPOSITION MODELLING (FDM)

Additive manufacturing (AM) is an automated and evolving process developed from the principle of layer-based technology. It is very effective for form, fit, feel good and functional prototypes. Additive manufacturing has gained momentum after advent of the various techniques to process materials. The major AM processes are material jetting or stereolithography (SLA), material extrusion or Fused Deposition Modelling (FDM), Binder Jetting or 3D-Printing, Powder Bed Fusion (SLS or SLM) and direct powder deposition (DPD). Depending on the material and design requirement appropriate process has to be chosen.

Fused Deposition Modelling (FDM) is a layer-by-layer deposition of prefabricated thermoplastic material. It is an extrusion process in which an extrusion head provides the material deposition in the x-y area according to the contour of the actual layer. It is a plotter-type device. A FDM machine consists of a heated build chamber equipped with an extrusion head and a build chamber. Various thermoplastic materials are available in different colours in the form of ribbons or strings [4]. FDM needs a support structure for forming a base; especially for complex models with overhangs. Two extrusion heads, each for build material and support material, are used. The schematic of FDM machine is shown in Fig 7.

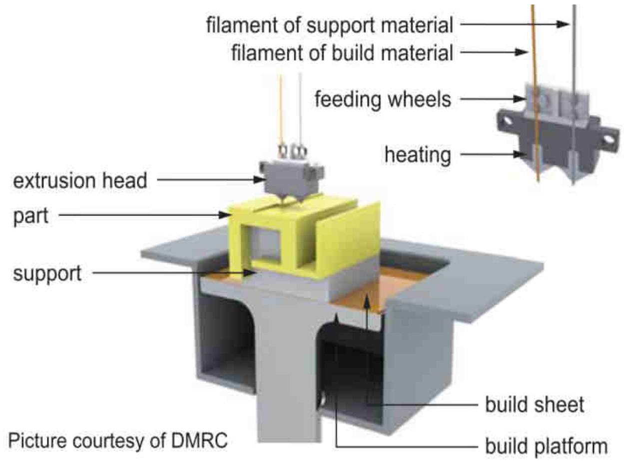

Fig.7: Layout of FDM machine components

Various advanced materials (thermoplastics) with special properties are available for being processed by FDM. ABS (acrylonitrile butadiene styrene) is the most commonly used material for FDM. Nearly 90% of the prototypes fabricated using FDM are made out of this material. Several derivatives of ABS with stronger mechanical properties are also available [5]. Other than this material, Polycarbonates (PC) can be used for greater loads and forces. New high strength and space qualified plastic, ULTEM can also be processed with FDM.

V. MATERIAL FOR ASTROSAT MODEL

The most commonly used material for the prototypes generated using FDM , is ABS. ABS stands for Acrylonitrile Butadiene Styrene and is a thermoplastic with good mechanical properties required for prototypes, form and fit, and functional prototypes. Hence this material was selected for the ASTROSAT model. The properties of the ABS material [5] are given in Table 1. The support structure required for ABS is of soluble type.

Table 1: ABS Material properties

Property	**Value**
Tensile Strength	36 MPa
Tensile Elongation	4.0%
Flexural Stress	61 Mpa
IZOD Impact notched	139 J/m
Heat Deflection	96°C

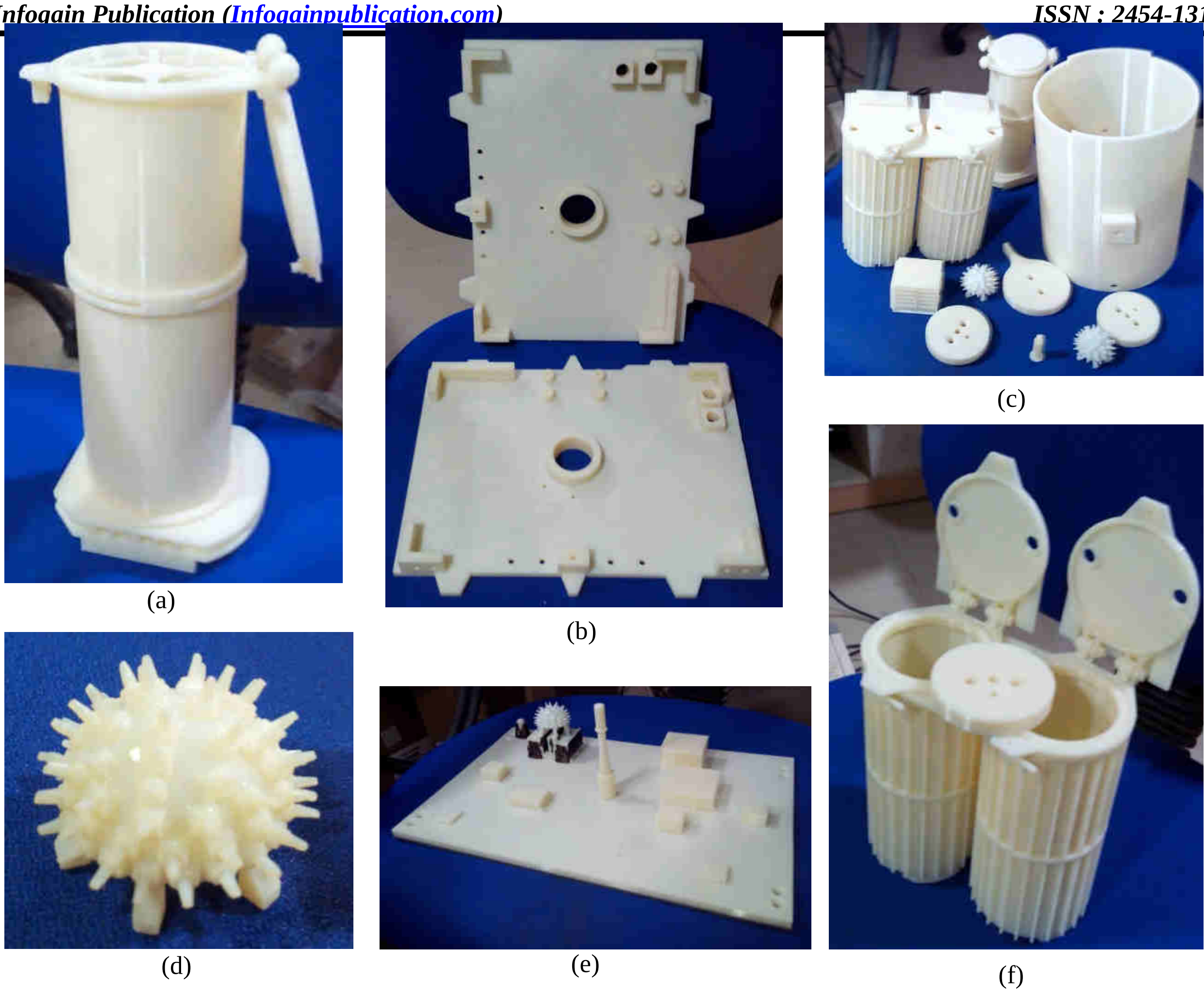

Fig.8: ASTROSAT model parts realized using FDM and Polyjet printing (a) SXT (b) Spacecraft decks (c) UVIT, SSM mechanisms (d)Phased Array antenna (e) Equipment deck and (f) UVIT

VI. PRINTING OF ASTROSAT ASSEMBLY PARTS

The UG NX CAD models were converted to STL (Stereolithography) format with triangle tolerance and adjacency tolerance set to 0.0025 and 0.12 respectively. These STL files were loaded into an STRATASYS INSIGHT software which generated the support material and tool paths according to the machine and machining parameters selected. The STRATASYS FORTUS 400 MC machine was selected for printing the majority of the parts of ASTROSAT MODEL. Due to the inherent complexity of two phased array antenna models, they were printed using STRATASYS OBJET printers. It is a polyjet printing process in which, UV LASER curable polymer material and support material is sprayed on the substrate. Then it is selectively cured based on the

Fig .9: Completely assembled ASTROSAT model in deployed condition.

contours in sliced data of the STL file.

For FDM process, the layer thickness of 0.254mm was selected. Various components printed are shown in Fig 8. The hinge mechanisms were printed as a whole, there by demonstrating the capability of additive manufacturing in printing the assembly. The orientation of the components were considered to achieve the maximum strength in printed parts. The support structures from the printed parts were removed by dissolving them in an appropriate solvent. The individual components were then assembled either through the application of adhesives or by employing fasteners. Final assembled model of the ASTROSAT is shown in Fig 9.

VII. CONCLUSIONS

In this work, the application of Additive Manufacturing technology and FDM in particular, to realize the complicated spacecraft models is demonstrated. Also the criticalities and aspects involved in design for additive manufacturing have been brought out. Such, models aid the demonstration of critical technologies during critical design reviews and give a better insight into the system. Additive Manufacturing technology opens a new door to the fabrication of space related components. Complex mechanisms can be prototyped and the functionality can be demonstrated effectively. The entire exercise gave us a good insight into design for additive manufacturing and realization. It served as a path for the future plans to exploit the strong potential that this technology holds.

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