भारत सरकार/GOVERNMENT OF INDIA
अंतरिक्ष विभाग/DEPARTMENT OF SPACE
विक्रम साराभाई अंतरिक्ष केंद्र/VIKRAM SARABHAI SPACE CENTRE
तिरुवनंतपुरम/THIRUVANANTHAPURAM – 695 022

संदर्भ / Ref: VSSC/CMSE/EOI/ABSG/2019 तिथि/Date : 25/10/2019

अभिरुचि की अभिव्यक्ति / EXPRESSION OF INTEREST

इसरो के प्रचालनात्मक प्रमोचन यानों के अपक्षरक नोज़लों के निर्माण के लिए विक्रम साराभाई अंतरिक्ष केंद्र, तिरुवनंतपुरम अभिरुचि की अभिव्यक्ति आमंत्रित करते हैं।

Vikram Sarabhai Space Centre, Thiruvananthapuram invites Expression of Interest for Manufacturing of Ablative Nozzles of ISRO's operational launch vehicles.

इच्छुक विक्रेता अपनी संदर्भ सं. VSSC/CMSE/EOI/ABSG/2019 का उद्धरण करते हुए, **दिनांक 25.11.2019 [04:00 PM] को या उससे पहले** निम्नलिखित पते पर अपनी अभिरुचि की अभिव्यक्ति दे सकते हैं:

Interested vendors can furnish their Expression of Interest quoting our reference No. VSSC/CMSE/EOI/ABSG/2019 **on or before 25/11/2019 [04:00 PM]** to the following address:

क्रय एवं भंडार अधिकारी / Purchase & Stores Officer
सीएमएसई क्रय / CMSE Purchase,
वट्टियूरकावु / Vattiyoorkavu PO,
तिरुवनंतपुरम / Thiruvananthapuram - 695013.
फोन/Ph: 0471-256 9290

हस्ताक्षरित/Sd/-
वरि. प्रधान, क्रय एवं भंडार / Sr. Head, Purchase & Stores

Invitation for Expression of Interest (EoI) for Manufacturing of Ablative Nozzles of ISRO's operational launch vehicles

October 2019

VIKRAM SARABHAI SPACE CENTRE (VSSC)

Indian Space Research Organization (ISRO)

Department of Space, Government of India

CONTENTS

1. OBJECTIVE OF EoI

ISRO's operational launch vehicles employ ablative nozzles for all of its solid motors and ablative throat insert for all of its liquid engines. Most of these ablative products are currently manufactured in-house with established and qualified process.

VSSC plans to outsource the manufacturing of the major ablative products to meet the increased launch demand of ten PSLV missions, two GSLV missions and four GSLV Mk3 missions per year, which is likely to increase in the coming years.

The objective of this EoI is to identify competent aerospace manufacturing industry to take up the manufacturing of ablative products as per the process document provided by VSSC, by setting up the necessary manufacturing facility in India.

The following are the products identified for manufacturing by industry:

1. PS1 nozzle for 1st stage of PSLV (10 nozzles/year)
2. PS0-XL nozzle for strap-on stage of PSLV (60 nozzles/year)
3. HPS3 nozzle for 3rd stage of PSLV (10 nozzles/year)
4. GS1 nozzle for 1st stage of GSLV (2 nozzles/year)
5. S200 nozzle for strap-on stage of GSLV-Mk3 (8 nozzles/year)
6. Liquid engine throat for Vikas engines of PSLV, GSLV & GSLV Mk3 (28 throats/year)

The indicated numbers are based on current demand, which is likely to increase in coming years. Also, ablative products for new launch vehicles under development at VSSC is also intended to be outsourced subsequent to design and process validation.

2. SCOPE OF WORK

2.1. Scope of work of prospective vendor:

2.1.1. Establishment of facilities for production, non-destructive testing, metrology, chemical testing and mechanical testing

2.1.2. Recruiting required manpower and getting them trained at VSSC

2.1.3. Procurement of raw materials identified by VSSC from the approved vendors and its acceptance testing

2.1.4. Realization of process tooling, fixtures, transportation containers, etc based on the design provided by VSSC

2.1.5. Realization of first-off products at party's facility as per the process document provided by VSSC, which will be qualified through testing at VSSC

2.1.6. Regular production as per the process document provided by VSSC

2.2. Scope of VSSC:

2.2.1. Providing process document of each product and all the necessary technical know-how for the manufacturing

2.2.2. Providing details of necessary manufacturing and testing equipments

2.2.3. Providing Rayon-based carbon fabric, High Silica fabric, Graphite throat block, Carbon-Carbon throat block as Free-Issue-Material (FIM)

2.2.4. Providing non-ablative FIMs like, metallic backup hardwares, fasterners, washers, O-rings, sealant putty, etc.

2.2.5. Providing specification and source of raw materials to be procured by party, namely, phenolic resin, PAN based carbon fabric and glass fabric (these materials shall be supplied by VSSC as FIM for first off products for qualification)

2.2.6. Providing hands-on training to manpower recruited by party at VSSC

3. MAJOR FACILITIES REQUIRED

The following are the major facilities required for realizing the above nozzles.

3.1. For Impregnation:

a) Impregnation plant with heating chamber upto 105^{o}C
b) Cold Storage of 4^{o}C
c) Fabric stitching machine

3.2. For tape winding:

a) Standard Prepreg cutting machine with profile cutting feature
b) Conventional tape cutting machine
c) Ø 1.5 m CNC horizontal tape winding machine
d) Ø 4 m CNC horizontal winding machine
e) Ø 4 m CNC vertical winding machine

3.3. For moulding and curing:

a) Ø 2m Hydroclave
b) Ø 3 m Hydroclave
c) Ø 1m Autoclave
d) Ø 4 m Autoclave
e) 180 KW Oven of size 3.5m x 3.5m x 3.5m
f) 250 T Hydraulic press with platen heating

3.4. For machining:

a) Ø 4m CNC Vertical Turning Machine
b) Ø 1.5m CNC Vertical Turning Machine
c) Ø 0.5m CNC Lathe
d) Radial Drilling machine
e) Milling machine of size 0.3m x 0.3m x 0.3m
f) Band-saw cutting machine with diamond coated blade

3.5. For bonding and assembly:

a) Resin mixer
b) Grit blasting facility of size 4m x 4m x 4m

3.6. For Non-Destructive Testing (NDT):

a) Dry coupled Ultrasonic equipment with probes & accessories
b) Phased Array Ultrasonic equipment with probes & accessories
c) 450 kV X-ray machine with manipulator
d) Digital Flat Panel X-ray Detector
e) Automatic Tap Tester equipment
f) Automated Ultrasonic C-scan System
g) 9 MeV LINAC System with manipulator

3.7. For dimensional inspection:

a) CMM of size 5m X 4m X 3m or Laser tracker
b) Standard dimensional inspection instruments

3.8. For chemical lab:

a) Densitometer
b) Soxhlet extraction apparatus
c) Viscometer
d) Standard lab equipment like weighing balance, oven, furnaces, etc.

3.9. For mechanical testing:

a) Universal testing machine with provision for testing upto 600◦C
b) Standard equipment for fabric testing

Adequate provisions should be planned for handling and storage of raw materials, in-process products and final products.

The expected total building area is around 3000 m^2 out of which 1800 m^2 will require 12m height crane hook and remaining will require 7m height crane hook. BARC clearance will be mandatory for X-ray facilities as per norms.

4. BRIEF DESCRIPTION OF PRODUCTS TO BE MANUFACTURED

Ablative nozzle employs passive cooling using ablative materials to protect the nozzle from extremely high heat of the rocket exhaust.

Ablation is a heat and mass transfer process in which a large amount of heat is dissipated in a very short period of time with a small sacrificial loss of material. Ablative composites are polymeric composites where the reinforcement is generally a high melting point fibre/fabric like rayon-based Carbon or High-Silica fabrics and the matrix is a high-char-yielding resin like Phenol-Formaldehyde.

Figure-1 depicts the ablative products identified for manufacturing in this EoI and their location in ISRO's operational launch vehicles.

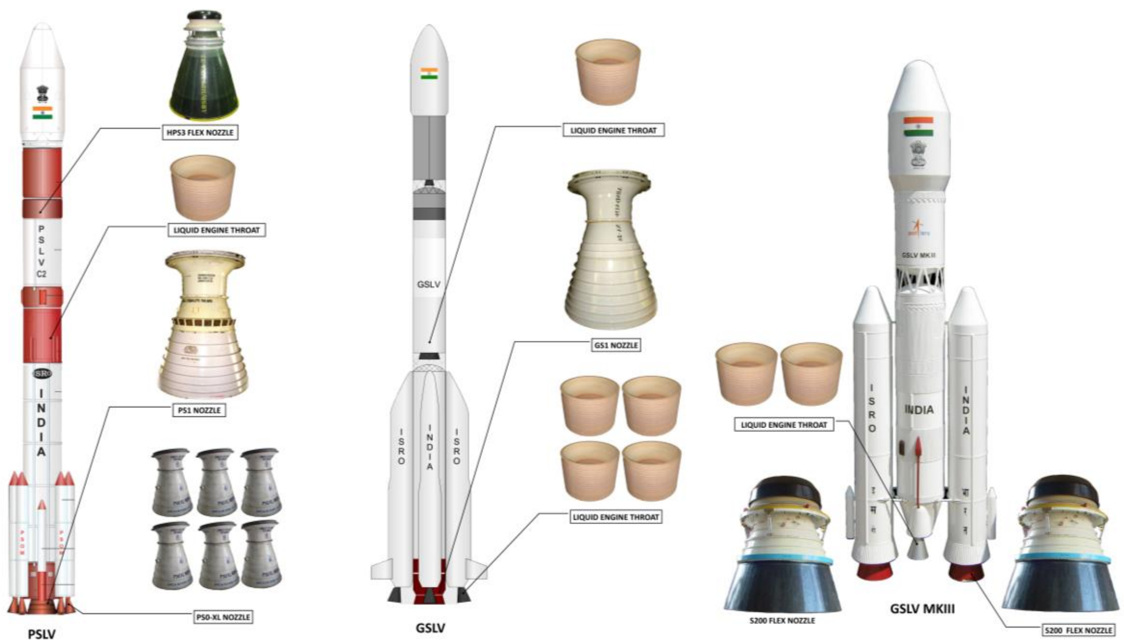

Figure 1: Ablative nozzles of ISRO's operational launch vehicles

Each of the products are briefly described in the following section, showing the overall sizes and salient features.

4.1. PS1 nozzle

The first stage nozzle of PSLV is a fixed external nozzle with conical divergent of area ratio 9, having four major ablative liners, 24 ablative inserts in divergent and three metallic backup hardwares. Figure-2 shows the schematic of nozzle with major components and salient dimensions. Each nozzle uses around 2750 m^2 of rayon-based carbon fabric and around 850 m^2 of high-silica fabric. The approximate work content for manufacturing one such nozzle is around 1100 technician man-days.

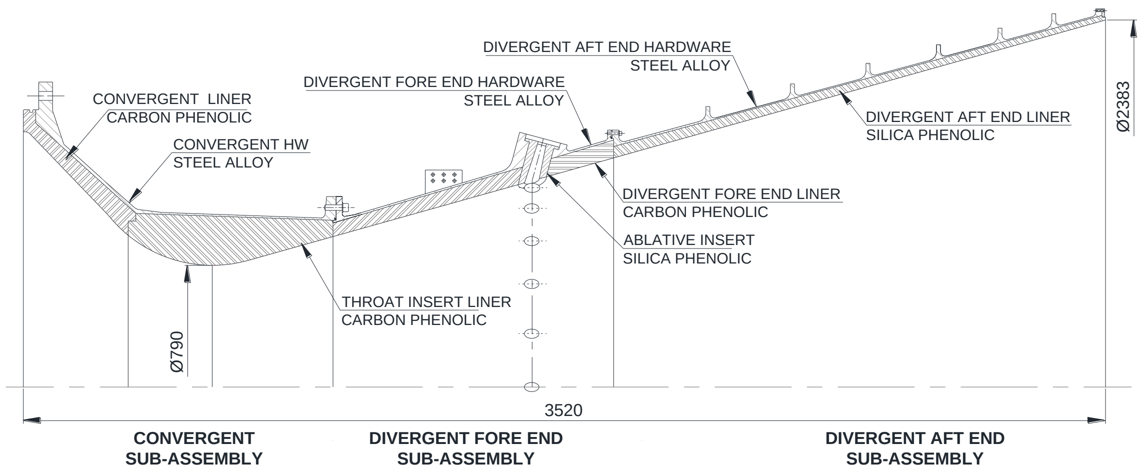

Figure 2: Schematic of PS1 nozzle

4.2. PS0-XL nozzle

The strap-on motor nozzle of PSLV is an external canted nozzle with conical divergent having three major ablative liners and two metallic backup hardwares. There are two variants of this nozzle, type-1 with ablative inserts and type-2 without ablative inserts. A standard version of PSLV uses two type-1 variants and four type-2 variants of the nozzle. Figure-3 shows the schematic of nozzle with major components and salient dimensions.

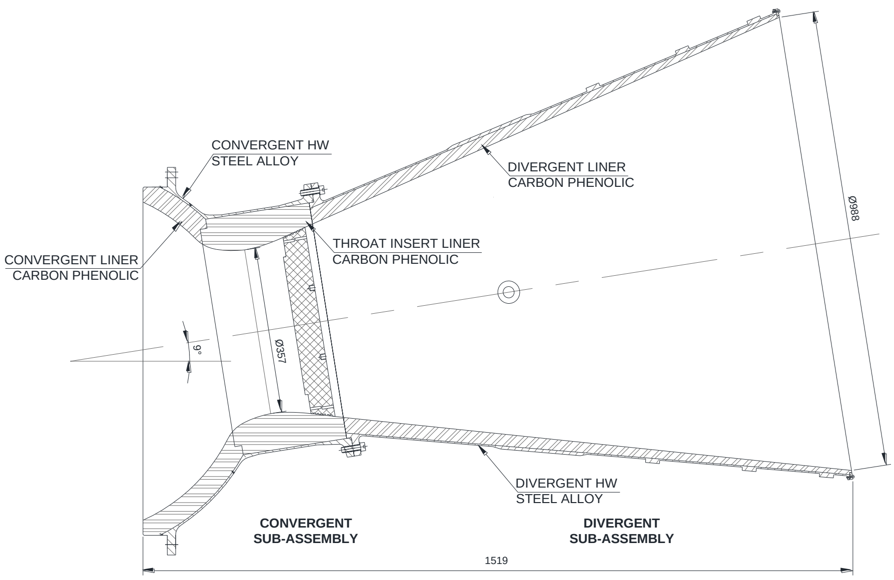

Figure 3: Schematic of PS0-XL nozzle

Each nozzle uses around 1050 m^2 of rayon-based carbon fabric. The approximate work content for manufacturing one such nozzle is around 450 technician man-days.

4.3. HPS3 nozzle

The third stage nozzle of PSLV is a sub-merged flex nozzle with contoured divergent of area ratio 70. The nozzle consists of flex-seal sub-assembly (which enables nozzle actuation during operation), Graphite/Carbon-Carbon throat, five ablative liners, two metallic backup hardwares and composite structural backup for the divergent region. Figure-4 shows the schematic of nozzle with major components and salient dimensions. Each nozzle uses around 725 m^2 of rayon-based carbon fabric and around 15 m^2 of high-silica fabric. The approximate work content for manufacturing one such nozzle is around 530 technician man-days.

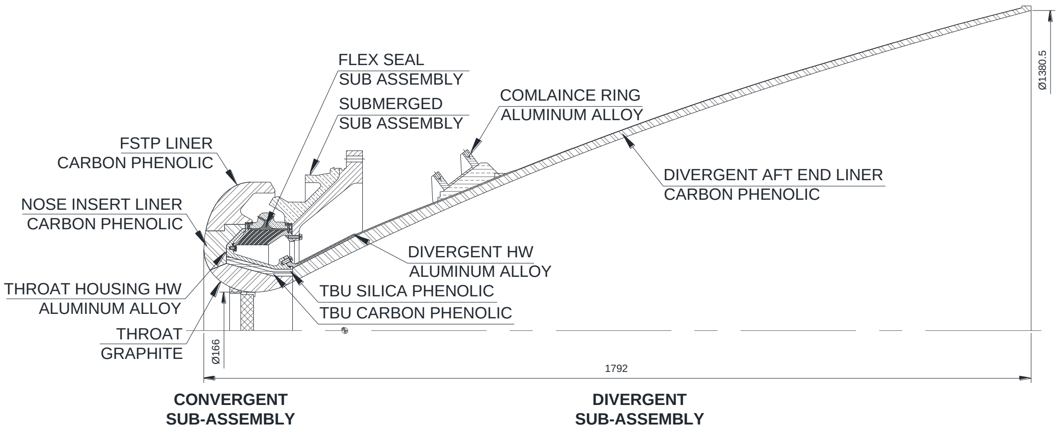

Figure 4: Schematic of HPS3 nozzle

4.4. GS1 nozzle

The first stage nozzle of GSLV is a fixed external nozzle with conical divergent of area ratio 9 which is similar to PS1 nozzle, only difference being non-existence of ablative inserts in divergent region. Figure-5 shows the schematic of this nozzle with major

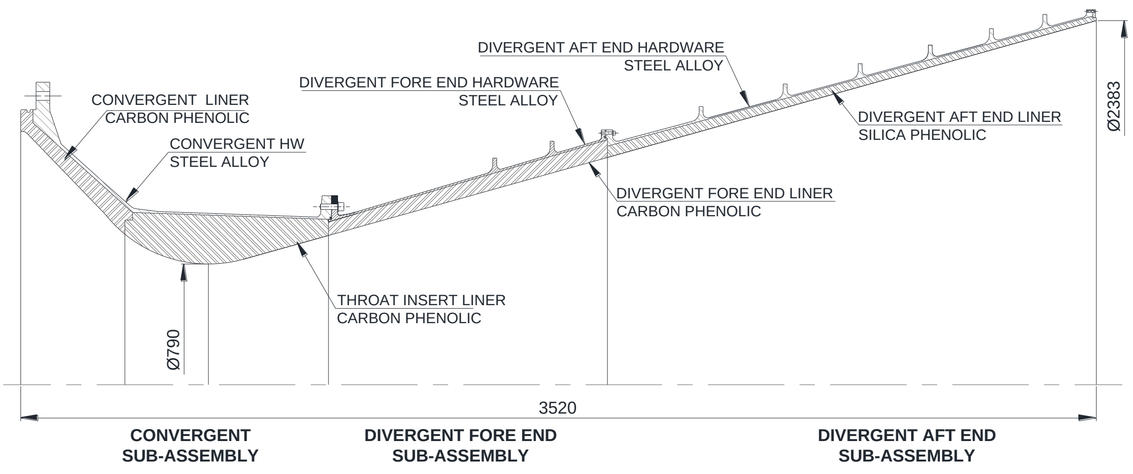

Figure 5: Schematic of GS1 nozzle

components and salient dimensions. Each nozzle uses around 2750 m2 of rayon-based carbon fabric and around 800 m2 of high-silica fabric. The approximate work content for manufacturing one such nozzle is around 900 technician man-days.

4.5. S200 nozzle

The strap-on nozzle of GSLV Mk3 is a submerged flex nozzle with contoured divergent having area ratio of 12. Figure-6 shows the schematic of the nozzle having eight ablative liners, four metallic hardwares and composite structural backup in addition to flex-seal. Each nozzle uses around 7750 m^2 of rayon-based carbon fabric and around 225 m^2 of high-silica fabric. The approximate work content for manufacturing one such nozzle is around 1960 technician man-days.

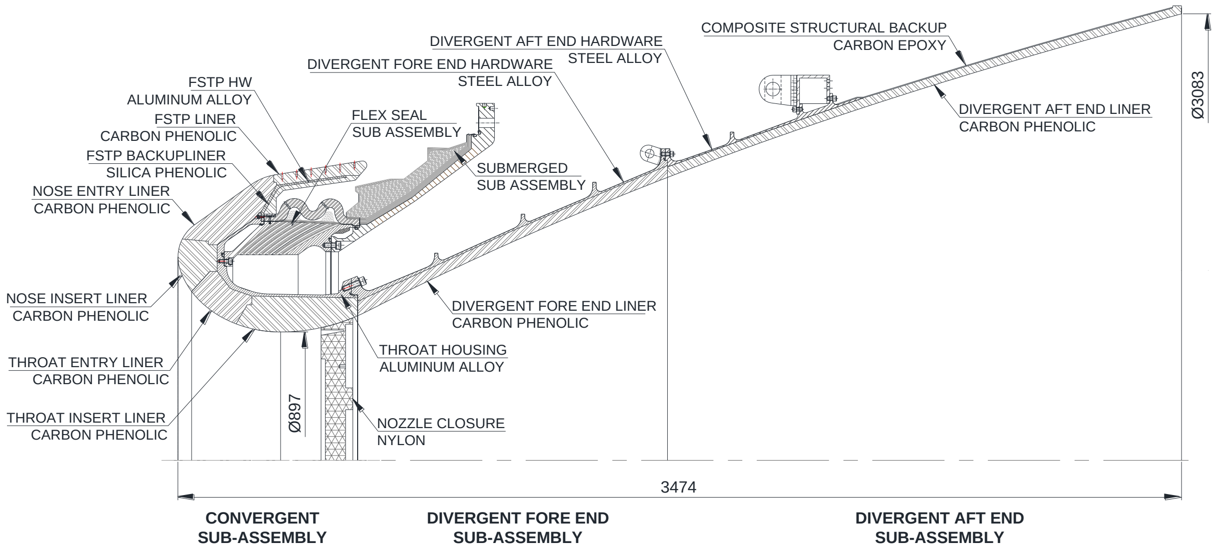

Figure 6: Schematic of S200 nozzle

4.6. Liquid engine throat

The liquid engine of all the three launch vehicles uses ablative throat made of silica-phenolic. The throat has two variants, namely conical and contoured versions as shown in figure-7. Each throat uses around 125 m^2 of high-silica fabric. The approximate work content in manufacturing one such throat is around 75 technician man-days.

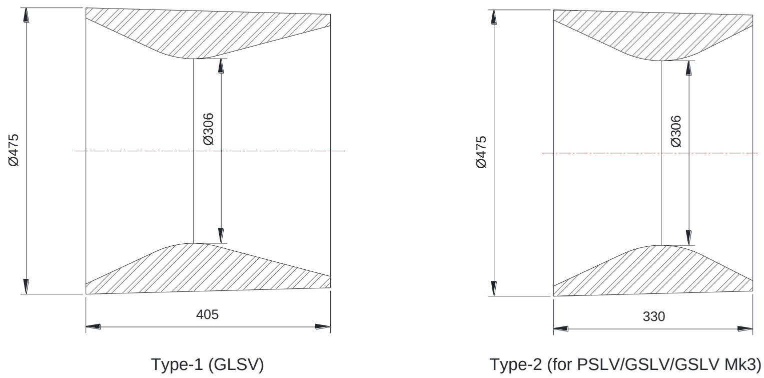

Figure 7: Schematic of liquid engine throat

5. BRIEF DESCRIPTION OF MANUFACTURING PROCESS

A nozzle assembly consists of two or more sub-assemblies, and each sub-assembly consists of one or more ablative liners bonded to metallic backup structural hardware or a composite backup is provided over the liner. A brief description of generic procedure for the fabrication of liner. Sub-assembly and nozzle assembly is given in following sections.

5.1. Liner processing

An ablative liner is processed by either winding prepreg tapes or layup of prepreg plies over a mandrel, curing the wound mass along with mandrel under simultaneous application of vacuum, temperature and pressure and machining the extracted cured liner as per the fabrication drawing. Figure-8 shows the flowchart of a generic procedure of liner fabrication.

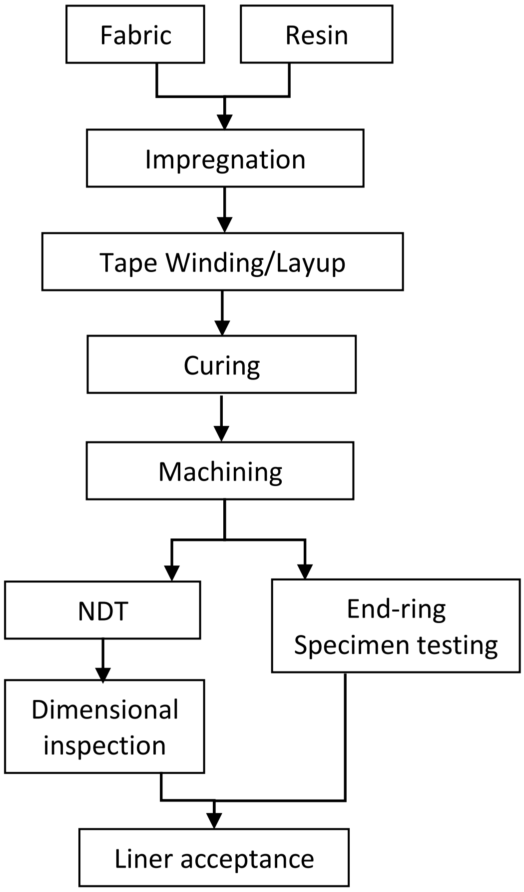

Figure 8: Typical flowchart of ablative liner fabrication process

A brief description of each of these stages is given below.

5.1.1.<u>Impregnation</u>

This process involves wetting of the reinforcement fabric (carbon or silica fabric rolls) with the phenolic resin to obtain 'prepreg' having specified resin content and advancement. The fabric after preheating passes under tension through a resin bath and squeeze rollers for getting the required resin content and then passed through heating zone maintained between 85 to 105ºC for achieving required advancement. The roll tension, gap between squeeze rollers and impregnation velocity are parameters to be controlled to achieve the required prepreg properties.

5.1.2. Tape winding/Layup

Tape winding is carried out on tape winding machines. The prepreg is cut into tapes of specified width in specified fashion (along warp/ 45º bias to warp/specific pattern) and wrapped around the mandrel to get the geometric shape of the liner. While mandrel provides the inner geometry, winding provides the outer geometry. Tapes are fed in between mandrel and a pressure roller for continuous compaction as it is being wound. The prepreg is heated to 60 to 90ºC just before being wound to increase the tackiness and cooled soon after to halt over advancement. The winding head travels along the mandrel surface to cover the entire mandrel. Tape width, pitch of winding head, roller pressure, tape tension are major parameters to be controlled during winding.

The layup is a manual operation in which plies cut to a specific shape are laid over the mandrel in a specific pattern. Debulking is often called for to achieve the required compaction.

5.1.3. Curing

The wound/laid-up product (along with the mandrel) is cured in appropriate curing chambers like, oven, press, autoclave or hydroclave following the specified cure cycle involving simultaneous application of temperature and pressure. While final soak temperature for the phenolic resin employed is 160ºC, the pressure is chosen based on the thickness of the individual liner, the range being 5 to 65 bar. Vacuum is necessary used throughout the curing to suck out the volatiles in real-time and also for general consolidation. A very slow heating and cooling rates (5 to 10ºC/hr) are necessary to achieve defect free products. The items undergoing hydroclaving need rubber bags, which are prepared to shape in advance using silicone rubber.

5.1.4. Machining

The cured liner is machined as per the fabrication drawing using vertical turning machines and lathes. As coolant is not permitted during machining, harder tools like poly-crystalline diamond tipped / tungsten carbide tipped tools are necessary. Typical cutting speeds of 40-50 m/min are used. Dust collection system is mandatory to suck out the machining dust in real time.

5.1.5. Dimensional Inspection

Machined liner is subjected to dimension inspection to ensure that the achieved dimensions are within the allowable tolerances. A combination of conventional metrology and CMM are employed.

5.1.6. Non-Destructive Testing (NDT)

The liner is tested for possible defects like delamination, cracks, voids, resin rich reasons, etc by ultrasonic testing and X-ray radiography in addition to visual testing.

5.1.7. End-ring specimen testing

Specimens are extracted from parted end-ring and tested for specified properties, depending on the criticality of the liner.

5.1.8. Liner acceptance

The liner acceptance is based on adherence to the approved process as confirmed by process log issued by online QC, acceptance of achieved dimensions, acceptance of NDT observations and acceptance of tested properties from end-ring specimens.

The non-conformances if any should mandatorily be cleared by the appropriate forum in VSSC before acceptance of the liner.

5.2. Sub-assembly operations

5.2.1. In cases of sub-assemblies having metallic backup hardware (issued as FIM), the identified liners are adhesively bonded to the backup hardware using suitable bonding fixtures. Two-part adhesive with limited pot life is used and hence bonding needs proper planning. Parts to be bonded are dry suited before bonding to ensure required interface conditions are met. Metallic bonding surfaces need to be prepared by suitable methods like grit blasting. Bonded parts are then machined as per sub-assembly fabrication drawing and subjected to dimensional inspection and NDT for acceptance.

5.2.2. In case of sub-assemblies having composite structural backup, the composite backup is provided directly on the liner. Glass-epoxy or Carbon-epoxy are the two materials used either by wet process involving wetting the fabric with resin and cutting and laying up of the resulting wet fabric over liner or dry process involving laying up of prepreg. The backup is then cured at 100-125ºC following specified cure cycle. The item is then machined as per sub-assembly fabrication drawing and subjected to dimensional inspection and NDT as done for liner.

5.2.3. The sub-assembly is subjected to dimensional inspection and NDT to detect possible defects like debonds, surface defects in liner, etc.

5.2.4. The sub-assembly acceptance is based on adherence to the approved process as confirmed by process log issued by online QC, acceptance of achieved dimensions and acceptance of NDT observations. The non-conformances if any should mandatorily be cleared by appropriate forum in VSSC before acceptance of the sub-assembly.

5.3. Nozzle assembly operations

5.3.1. Two or more sub-assemblies of a nozzle are mechanically assembled using fasteners torqued to specified limits. All the interface elements like fasteners, washers, O-rings, sealant putty, etc will be FIMs from VSSC.

5.3.2. All the interfaces are verified for necessary design conditions in a trial-assembly before the final assembly and matched with expected interface conditions from achieved dimensions of sub-assemblies.

5.3.3. Assembled nozzle is then placed inside a specially designed transportation container and despatched.

6. PROCESS TOOLING

6.1. Each liner requires a specific mandrel for fabrication, with provisions for vacuum application, vacuum bagging, mounting on winding machine, handling, etc. The vendor shall realize each of the mandrels in adequate numbers as per the mandrel design provided by VSSC.

6.2. Fixtures are necessary for bonding of liners to backup hardwares and for machining of liners and sub-assemblies. The vendor shall realize each of these fixtures as per the fixture design provided by VSSC.

6.3. Assembly stands are necessary for nozzle assembly operations, which shall be realized by the vendor as per the design provided by VSSC.

6.4. The vendor shall also realize transportation containers for safe handling of finished products to the place specified by VSSC in adequate numbers.

7. QUALITY REQUIREMENT

7.1. Maintaining necessary quality control during manufacturing is the responsibility of the vendor

7.2. The manufacturing shall be strictly as per the process document provided by VSSC

7.3. Considering process intensive nature of composites in general and the single use nature of ablative products in particular, strict online quality monitoring is mandatory. VSSC may depute resident engineers for online quality surveillance.

7.4. VSSC will conduct periodic quality audit for verifying adherence to the quality protocols.

8. DELIVERY SCHEDULES

The vendor should be able to meet the delivery schedule as follows:

8.1. The procurement and commissioning of the facilities should be completed within a period of 18 months from the date of order placement

8.2. First-off products should be delivered within 24 months from the date of order placement

8.3. Subsequent to clearance for regular production, products shall be delivered at regular intervals as follows:

- PS1 nozzle: 1 nozzle every 36 days
- PS0-XL nozzle: 5 nozzles every month
- HPS3 nozzle: 1 nozzle every 36 days
- GS1 nozzle:1 nozzle every 6 months
- S200 nozzle:1 nozzle every 45 days
- Liquid engine throat: ~5 throats every 2 months

9. VENDOR EVALUATION CRITERIA

The following are the essential criteria to be fulfilled by the vendor:

9.1. Should be an aerospace manufacturing industry having at least three orders worth ₹1 crore or more in the past three years

9.2. Should have experience and facilities for general composite manufacturing

9.3. Should have healthy financial conditions with minimum turnover of ₹50 crores consistently for past 3 years

9.4. Should have the ability to invest large capital (more than ₹100 crores) over long term (more than 3 yrs)

9.5. Should have end-to-end capability for

i. Planning/identifying and procurement of manufacturing equipment
ii. Design and realization of tooling
iii. production planning and process control
iv. independent quality control system
v. qualified and calibrated inspection/testing facilities

9.6. Should have adequate and competent manpower to take up aerospace manufacturing of similar complexity

9.7. Should setup the essential manufacturing facilities in India under one-roof listed in section 3 for

i. Impregnation

ii. Tape winding
iii. Moulding and curing
iv. Machining
v. Bonding and assembly

Note: *Sub-contracting of operations related to these facilities will not be permitted and details of equipment proposed to be procured is to be shared with VSSC*

9.8. It is preferred to have the NDT and other inspection facilities in the vicinity of manufacturing facilities. In case the party plans to outsource these activities, it should be with the concurrence of VSSC. However, the responsibility of meeting the quality requirement and delivery schedule lies with the party.

Vendors who express interest will have to mandatorily visit VSSC on a mutually convenient date and present their interest and capabilities to meet above requirements.

VSSC also reserves the right to visit the party and verify the proofs for the claims made by the party for meeting the vendor evaluation criteria.

10. SUBMISSION OF EoI

Interested vendors who understand the technical requirements as mentioned in this document and confirm their eligibility to the evaluation criteria given in section 9 are requested to express their interest to take up this manufacturing activity.