

## FESHM 10210: EQUIPMENT TRANSPORT

### Revision History

<b>Author</b>	<b>Description of Change</b>	<b>Revision Date</b>
Jeremiah Holzbauer	<ul style="list-style-type: none"><li>• Initial Release</li></ul>	April 28, 2022

**TABLE OF CONTENTS**

<b>1.0</b>	INTRODUCTION AND SCOPE.....	3
<b>2.0</b>	DEFINITIONS .....	4
<b>3.0</b>	RESPONSIBILITIES.....	6
<b>3.1</b>	Division/Section/Projects (D/S/P).....	6
<b>3.2</b>	Lead Engineer.....	6
<b>3.3</b>	The Mechanical Safety Subcommittee (MSS).....	6
<b>3.4</b>	MSS Transportation Panel.....	6
<b>3.5</b>	Facilities Engineering Services Section Transportation Services .....	6
<b>4.0</b>	PROGRAM DESCRIPTION .....	7
<b>4.1</b>	Transport – Assessment of Critical Level .....	7
<b>4.2</b>	Documentation and Review of Transportation Plan .....	7
<b>4.3</b>	Modifications to a Compliant Transportation Plan .....	8
<b>4.4</b>	Technical Requirements .....	8
<b>5.0</b>	PROCEDURES .....	8
<b>5.1</b>	Critical Transport Definition and Assessment .....	8
<b>5.1.1.</b>	Critical Transport Assessment Table.....	9
<b>5.1.2.</b>	Risk Factor Description and Guidance .....	11
<b>5.1.2.1</b>	Cost/Value .....	11
<b>5.1.2.2</b>	Technical Risk Factors .....	11
<b>5.1.2.3</b>	Transportation Complexity Factors .....	12
<b>5.2</b>	Minimum Critical Transportation Documentation Requirements.....	13
<b>5.3</b>	MSS Transportation Panel Recommendation Process .....	14
<b>5.3.1.</b>	Definition of Transportation Milestones .....	15
<b>5.3.2.</b>	Transportation Milestone Review.....	17
<b>5.3.3.</b>	Ongoing Repetitive Transports.....	18
<b>5.3.4.</b>	Post Transportation Report.....	18
<b>6.0</b>	CRITICAL TRANSPORT PLAN CONTENT .....	19
<b>7.0</b>	TRANSPORT DOCUMENTATION AND RECORD RETENTION .....	19
<b>8.0</b>	10300 Equipment Transport Technical Appendix .....	20

## 1.0 INTRODUCTION AND SCOPE

This chapter outlines the requirements for equipment transport planning and approval associated with critical transports. In general, a critical transport is one that involves over the road, air or sea transport of equipment that could have a significant negative effect on a project or on Fermilab either through cost increase, schedule delays or negative public relations if the transport is unsuccessful. Although this chapter is not required for other less demanding equipment transport the general guiding principles can be used to help reduce risks in those cases. The procedure for determining critical transports and their review is defined in detail in Section 5 and shown schematically in Figure 1.

The requirements and processes contained here are consistent with and intended to be used in conjunction with applicable sections of the Fermilab Engineering Manual (FEM), Environmental Safety & Health Manual (FESHM), and Quality Assurance Manual (QAM).

Transportation of critical equipment requires planning to reduce the risk of equipment damage. Consistent with Work Planning and Control best practices and the Engineering Manual, it is important to ensure that proper preparation, documentation, review, and approval be given. Projects can incur substantial cost and schedule penalties if critical equipment is damaged during transportation. While transportation activities managed by vendors and partners are specifically excluded from the requirements of this chapter, the transport of equipment once Fermilab takes ownership is subject to this chapter's oversight. Care should be taken during partner/vendor planning to ensure that they have sufficient transportation experience, and that documentation/tooling is provided to Fermilab such that their successful transport designs/configurations can be repeated by Fermilab personnel.

Careful planning of work assures that it is performed safely and efficiently. All transportation activities shall be subject to a level of work planning and control commensurate with the criticality and the risk. Developing a transportation plan ensures the scope of work is understood, appropriate documentation is generated, all hazards have been identified, mitigation efforts established, and all affected personnel understand how the transport will proceed. The MSS Transportation Panel should be engaged early in the design process to ensure that this aspect is fully incorporated into the design and that documentation requirements are understood.

Additional requirements that may be applicable for equipment and procedures used as a part of the Transportation Plan are found in other FESHM chapters. In particular, FESHM 2060 Work Planning and Control has direct applicability. Personnel involved in any aspect of the transport activities shall be trained per the applicable ES&H training requirements.

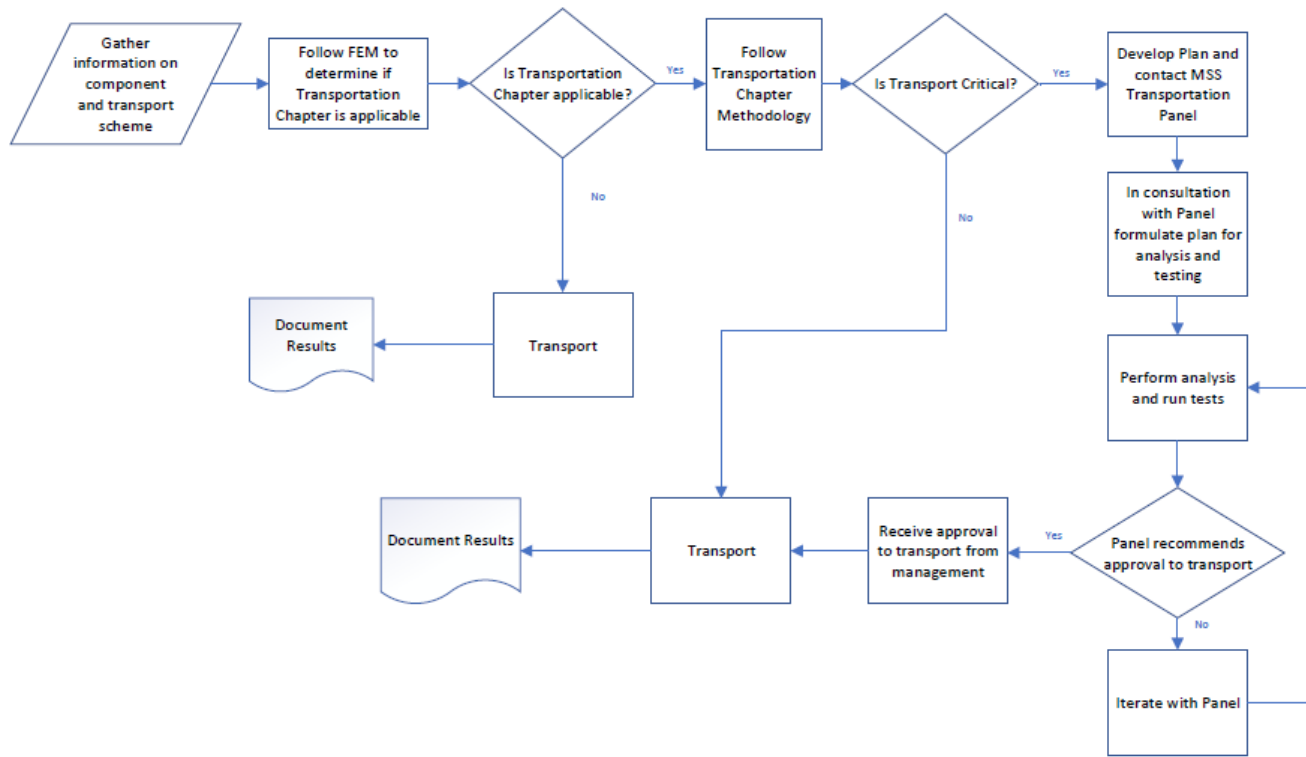


Figure 1 - Schematic layout of critical transport planning and review

## 2.0 DEFINITIONS

**Engineering Note** – A document demonstrating that a given component satisfies the requirements of the applicable Code, federal regulations, and FESHM requirements. Engineering notes may be required for Below-the-Hook Lifting Devices, Powered Industrial Truck Attachments, and/or Structures used as part of the equipment transportation process.

**Lead Engineer** – The qualified person with overall responsibility for preparing and executing the Transportation Plan.

**Material Move Request** – An electronic form which can be found on-line at [Service Now](#), the Fermilab Service Desk. This form is used to arrange for onsite moves by the Facilities Engineering Services Section Transportation Services.

**Panel Member** – A panel member shall be qualified person.

**Qualified Person**- a person who, by possession of a recognized degree or certificate of professional standing, or who, by extensive knowledge, training and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

**Transportation Milestone** – Significant stages during the design and validation process of a project will be defined by the Panel as Transportation Milestones. These are specific points where the Panel deems it should exercise its oversight authority. These milestones will be correlated with significant transport risk (e.g. end of engineering effort, prior to first transport, first transport in a significantly new configuration). Total milestones per type of device to be transported will generally be limited to one, with two or three milestones reserved for the most complex transports. Transportation milestones are independent from any project milestone/schedule management process (e.g. Primavera P6) and managed only by the Transportation Panel. Timing and documentation expectations for each Transportation Milestones are set during the initial assessment interaction with the Panel.

**MSS Transportation Panel** – a subpanel of the Mechanical Safety Subcommittee that deals with the critical transportation of equipment. The panel provides overall guidance and recommendations on developing the transportation plan.

**Transportation Failure Mode and Effect Analysis** – An assessment of the potential failure modes during transportation-related activities including design failures, process failures (human factors), and impacts of external factors including severity, likelihood, and rapidity of detection. This is designed to be a living document helping to drive design and mitigation efforts to ensure a low total risk from all potential failures. The template and guidance document can be found at ED0012422. This is referred to herein as a TFMEA to distinguish this from the FMEA specified in FESHM 5032.

**Transportation Plan** – In the design phase, the transportation plan is an organizational document that lays out the process by which the risks of transportation will be managed. This process may include a list of documents that will be generated, the tests that will be done, and analyses that will be performed, demonstrating that transportation is being included in the design and will be analyzed. Before each Transportation Milestone can be recommended the actual set of documents describing the procedures, risks, testing results and approved analysis for shipping critical equipment should be assembled. These documents may include

- Updated risk assessment (identification of critical components, risks and TFMEA)
- references to specifications
- drawings
- analysis
- description of testing
- travelers, procedures, acceptance criteria, and other QA/QC documentation
- conditions that constitute a viable, risk-reducing transport

A more detailed description can be found in Section 5.2.

**Work Planning** – Systematic process for determining methods for completing the assigned task safely and efficiently. The process includes defining the work to be performed and the methods for performing the work, identifying the hazards and their controls, hazard analysis (possibly a written one) and a pre-job briefing. (Reference: FESHM 2060: WORK PLANNING AND HAZARD ANALYSIS).

## 3.0 RESPONSIBILITIES

### 3.1 Division/Section/Projects (D/S/P)

The Division/Section Head or Project Manager (where applicable) is responsible for implementing this program. Specifically, he/she is responsible for:

- Assuring, through the line management, that employees assigned to perform the requirements of this Chapter are qualified to perform the work assigned.
- Final approval of Transportation Plans and shipments.

### 3.2 Lead Engineer

- Executing the requirements of this chapter.
- Coordinating and leading the communication with the MSS Transportation Panel.
- Coordinating and leading the communication with the appropriate Division/Section Head or Project Manager.
- Ensuring documentation is properly completed and stored according to this Chapter.
- Submitting the Material Move Request (MMR)

### 3.3 The Mechanical Safety Subcommittee (MSS)

- Setting up and maintaining the membership of the Transportation Panel.
- Serving in a consulting capacity on all Transportation Chapter matters.

### 3.4 MSS Transportation Panel

- Establish and maintain requirements for minimum risk assessment and planning documentation for critical transports
- Maintain the equipment transport technical appendix including best practices and lessons learned.
- If requested, monitor the process for creating and checking transportation documentation and preliminary tests presented by Lead Engineer are being followed.
- Providing a recommendation to Division/Section Head or Project Manager.

### 3.5 Facilities Engineering Services Section Transportation Services

- Transporting incoming material from the receiving dock to its end-user.
- Operation and inspection of Transportation Services' vehicles used for onsite transfers of material and maintaining them in a safe operating condition.
- Moving materials onsite as requested by other divisions and sections.

## 4.0 PROGRAM DESCRIPTION

### 4.1 Transport – Assessment of Critical Level

To determine if the transport under consideration is subject to the requirements of this chapter, a transport assessment is to be performed. The transport assessment will determine if the transport is a Critical Transport by considering the equipment cost, technical risk factors and complexity factors. The procedure for performing the assessment is described in Section 5.1 of this chapter. Transports which fall under the scope of this chapter shall be planned and executed in accordance with the requirements of this chapter and any other appropriate FESHM chapters.

Transports deemed to not be a critical transport should follow standard lab procedures and lessons learned best practices.

### 4.2 Documentation and Review of Transportation Plan

After having determined that the transport under consideration requires review by the MSS Transportation Panel (i.e., is a critical transport), the Lead Engineer is responsible for providing appropriate safety, risk, and planning documentation to the MSS Transportation Panel. The minimum documentation includes a Risk Assessment and Transportation Plan. The Risk Assessment includes completing a Prevention through Design Table and a Transportation Failure Mode and Effects Analysis (both found in ED0012422). The Transportation Plan includes a description of the scope of the transport and a plan for identification and mitigation of technical transport risks, further detailed in Section 5.2.

A Critical Transportation Plan shall be completed to summarize key information regarding the transport. A list of the information is given in Section 5.2.

The transportation safety analysis, evaluation, and review shall be directed to all aspects of the transport. These include but are not limited to:

- Hazards to personnel both performing and monitoring the transport activities
- Roadway, rail, air, waterway hazards as applicable including lifting & material handling between transportation modes Safety of the equipment transported.

The analyses and resulting documentation shall detail the mitigation and plans for the safety of personnel and equipment to be transported. The plan shall also include a description of any inspections or tests required after transport including their documentation (i.e., Acceptance Criteria, Travelers, Procedures for incoming QC).

Specifications to be provided to vendors/sub-contractors for equipment transportation via Fermilab Procurement shall be included in the Transportation Plan. While agreement regarding transport methods between Fermilab and transportation vendors/sub-contractors is important, the safe transport of the Fermilab equipment is, in general, the vendor's responsibility.

All documentation provided to the Transport Panel should be stored, reviewed, and approved as necessary in Teamcenter.

### 4.3 Modifications to a Compliant Transportation Plan

Any subsequent proposed changes in implementation of a previously approved Transportation Plan (already in compliance with this chapter) shall meet the requirements of this chapter. Modifications shall be documented in an Amendment to the original Transportation Plan documentation. This Amendment shall be reviewed in the same manner as the original plan and requires D/S/P approval.

### 4.4 Technical Requirements

A Technical Appendix to this chapter contains documents related to transportation reviews and serves as a repository for information that can benefit planning for future shipments. The Appendix will include:

- References to consultants or companies that can be contacted for technical support or component testing
- Expected shock loads and other inputs during various types of transport (road, rail, air, etc.), based on literature or data from previous transports
- References to MIL, BS EN ISO, ASTM, and other standards related to equipment transportation
- Failure modes of various types of materials and structures as well as relevant fatigue/failure engineering calculations
- Transportation system design guidance
- Instrumentation system design guidance
- Summaries of and references to successful Transportation Plans

## 5.0 PROCEDURES

All transports deemed to be ‘Critical Transports’ as defined below should comply with the requirements defined in this chapter. These requirements include receiving positive MSS Transportation Panel Recommendation prior to transport. The relevant D/S/P shall give final approval to transport. The documentation required to satisfy the requirements will vary based on the complexity and scope of the transportation in question. This section defines:

- An assessment to determine if the transport in question is a Critical Transport (Section 5.1)
- Minimum documentation expectations for transports that are deemed Critical (Section 5.2)
- The process by which the MSS Transportation Panel provides a recommendation for Critical Transports including a description of the additional required documentation (Section 5.3)

In addition to this, this section will give guidance for the required documentation/analyses including structure, content, examples, and technical references based on previous experience.

### 5.1 Critical Transport Definition and Assessment

A wide spectrum of equipment transportation occurs during the standard course of the Lab’s business. While the content of this Equipment Transport Chapter could be useful for all transports, the additional design/documentation requirements and recommendation process only applies to transports deemed to be Critical Transports. The criteria laid out below determines if an equipment transport must be managed with this higher standard.



The Lead Engineer for an equipment transport is responsible for ensuring this assessment is done, and any resulting triggered processes or requirements are followed in the required timeframe before shipment. *This assessment should be completed as early in a design lifecycle as possible to have maximal positive impact on the design and transport process.*

### **5.1.1. Critical Transport Assessment Table**

For the transportation being considered, a graded approach will be used based on several risk factors, including cost, technical complexity, and logistical risks. Table 3 lists the risk factors along with their associated risk score. For each transport, the score of all applicable risk factors should be determined. The summed total of the risk scores for the applicable risk factors determines if a transport is a Critical Transport.

- Additional and clarifying information for certain risk elements can be found in Section 5.2.
- The MSS Transportation Panel can be contacted for clarification or other assistance when completing this assessment
- A total score of the assessment in *Table 1* of five (5) or greater defines the transport activity in question as a Critical Transport
- *Note: If the cost of replacement of a single shipment/transport is less than \$100k, the transport is NOT classified as a Critical Transport regardless of other risk scores.*
- The technical and procedural information in this chapter *may still be useful and should be reviewed.* The MSS Transportation Panel may be voluntarily involved at the discretion of the Lead Engineer.

**Table 1 -Critical Transport Assessment Table**

<b>Risk Factor</b>	<b>Risk Score</b>	<b>Score for this Transport</b>
Cost of Replacement, < \$100k not classified as Critical Transport	1 point per \$100k of total cost of replacement of a single transportation load	
Design includes Brittle Ceramic Components	1 point	
Design includes significant composite material elements	1 point	
Design includes Brittle Crystalline Components	2 points	
Design includes delicate electronic components	1 point	
Design includes fatigue-sensitive items with low frequency resonances	1 point	
Device must be shipped while maintaining tight alignment tolerances	1 point	
Device must be shipped under vacuum or pressurized	2 points	
Design contains cantilevered, pendulum, or under-supported elements capable of motion during transportation	2 points	
Device includes features that are sensitive to environmental factors likely to be encountered in transport	1 point	
Transport will include a non-standard/custom transportation system	2 points	
Critical/high-risk transport activities will be performed outside the supervision/control of FNAL personnel	2 points	
Transport will include ship, rail, or air transportation	1 point for each mode	
Total Score for Transport If the total score for the transport is five (5) or higher, the transport will be considered a Critical Transport.		

### 5.1.2. Risk Factor Description and Guidance

This section provides more context/details about each technical risk factor in Table 3.

#### 5.1.2.1 Cost/Value

- Object costs should be estimated at replacement value (including labor) assuming a *total loss of the entire load* during transport. Partial loss or repairable damage scenarios should not be considered for this category.
- Loss of non-FNAL shipping hardware should not be considered (e.g. if a shipment on a transport shipping vessel is lost at sea, do not consider cost of the shipping container if it is not owned by Fermilab or the ship itself).
- Calculate the total value of the objects being transported. If more than one object is being transported, sum their total costs.

#### 5.1.2.2 Technical Risk Factors

For a given item being transported, consider the following categories of sensitivities that contribute to the technical risk. For a shipment of multiple items/assemblies, identify the number of sensitivities for each assembly separately and choose the highest value.

- Design includes Brittle Ceramic Components: Design includes ceramic RF windows, electrical feedthroughs, isolators, etc. which might be damaged by sharp shocks experienced during drops, rigging, or highest acceleration events during transport.
- Design includes significant composite material elements: Design includes structural components made principally of composite materials such as G-10 or other fiberglass supports, epoxy joined materials, etc. which might be damaged during sharp shock events.
- Design includes Brittle Crystalline Components: Design includes large crystalline objects that might be sensitive to cracking/damage during sharp shock events (detector elements, thermal pyrolytic graphite, high voltage feedthroughs, etc.)
- Design includes delicate electronic components: Design includes electronic components or assemblies of electronic components that might be sensitive to either cracking/breaking during sharp shocks or fatigue during sustained vibration excitation (large CCD structures, large circuit boards, rack-mounted electronics units, fatigue-sensitive solder connections, etc.)
- Design includes fatigue-sensitive items with low frequency resonances: Design includes items/connections (thin-walled bellows, long thin-walled tubing with fixed interfaces, etc.) that have potential for displacement large enough to cause significant fatigue. These elements are of special concern if they have the combination of low-stiffness and significant mass needed to give a low resonant mechanical frequency (in the frequency bands typical of transport vibrations) which may cause the object to experience large numbers of cycles during transport.

- Design includes precisely aligned structures: Any internal structures that are aligned to high tolerances or are weakly constrained that may be disturbed/shifted by either large shocks or vibrational creep, especially forces in directions different than the design loads (e.g. >1 g acceleration against gravity, sizable transverse loads)
- Device must be shipped under vacuum or pressurized: Devices that must be shipped either under significant vacuum or pressure may pose additional risks due to failures that cause loss of pressure/vacuum even though the majority of the mechanical assembly is intact.
- Design contains cantilevered, pendulum, or under-supported elements capable of motion during transportation: Under-supported masses capable of motion (cantilevered masses, adjustable components that cannot be locked in place, pendulum effect of vertically supported weight, etc.) where the acceleration of transportation could cause a significant amount of motion even if a structure designed to move.
- Device includes features that are sensitive to environmental factors likely to be encountered in transport: large changes and extremes in temperature and humidity are possible during transport as well as exposure to rain, snow, hail, strong winds, and other inclement weather effects. This category applies if the device is significantly sensitive to any to any of these likely factors without additional/significant packaging.

### 5.1.2.3 Transportation Complexity Factors

Certain transportation factors increase the level of difficulty and will require more rigorous planning, documentation, and review. For example, a standard assembly transport done on-site must be reevaluated when shipping overseas. Consider the list of transportation complexities below for use in Table 1.

- Transport will include a non-standard/custom transportation system: A device where a custom transportation packaging, isolation frame, and/or trailer is expected to be designed specifically for this purpose. This includes significant transportation of uncompleted assemblies during production. Exception: Unmodified packaging that has been designed by the device vendor for safe transportation that has been used extensively and successfully in the past.
- Critical/high-risk transport activities will be performed outside the supervision/control of FNAL personnel: This category is triggered when specific activities must be controlled to a higher tolerance than can be routinely expected from typical commercial shipping company handling procedures, and risk cannot be mitigated by close supervision/monitoring by FNAL personnel. For example:
  - Tractor/trailer road speed must be limited to below the posted speed limit to reduce vibration
  - Loading/Unloading with a fork truck is not allowed to reduce shock loads

- Package must be handled gently, i.e. cannot be thrown or tossed, or must be in a specific orientation relative to gravity.
- Transport will include ship, rail, or air transportation: Ship, air, and rail transportations are of specific concern because of the different vibrational environments and the significant potential for logistical and personnel mistakes during intermodal hand-offs. If any segment of the item transportation includes ship, air, or rail travel, this item is triggered. It would be noted that in some specific cases these can be triggered twice (e.g. river barge and ocean shipping vessel would be distinct and should be counted individually).

## 5.2 Minimum Critical Transportation Documentation Requirements

All Critical Transports are defined by their significant risk due to potential failures and associated consequences. Therefore, the minimum documentation for these activities is an assessment of these risks and a plan to manage and minimize these risks.

Risk Assessment Documentation (Templates found in ED0012422):

1. Prevention through Design Table (PtD Table) must be completed considering all transport activities (including but not limited to preparation for shipping, loading of the transport system, transportation, unloading, and transport closeout activities that might detect transport damage including inspection and re-configuration if necessary) specifically covering the following topics:
  - a. Personnel safety risks during all activities
  - b. Design features that may be desired (reduce technical risks, simplify/streamline transportation activities) during transport activities
2. Transportation Failure Mode and Effects Analysis (TFMEA) must be completed considering all transport processes:
  - a. Potential failure modes of each at-risk component of the device being shipped and the transportation system (e.g. vibration isolation system, shipping restraints) including severity of each failures impact, likelihood of the failure, and detectability of each failure.
  - b. Potential human factor failure modes of each procedure that must be completed during a Critical Transport (e.g. improper installation of shipping restraints, failure to torque transportation system fasteners sufficiently) including severity of each failures impact, likelihood of the failure, and detectability of each failure.
  - c. Potential external risk factors such as inclement weather, mechanical issues with the transport vehicles, traffic accidents/incidents, and significant delays in transport from reasonable causes.
  - d. Note: *A Transportation FMEA is distinct from the FMEA called for by FESHM 5032, and the two forms should not be considered interchangeable.*

Not all factors may be known early in the design and planning process for a Critical Transport. These risk assessment documents should be completed using the design/planning information available at the start of transport planning. These documents are expected to be living documents, which are updated and refined at major design and planning milestones.

The transportation risk management planning for a Critical Transport must be documented in a detailed Transportation Plan.

Transportation Plan:

1. Detailed description of the scope of the transport in question
  - a. Description of equipment to be transported
  - b. Number of devices/transporters
  - c. Basic schedule of transport activities
  - d. Responsibilities matrix for transport activities.
2. Plan for identification and mitigation of technical transport risks
  - a. Summary of previous relevant, related devices that have been transported including lessons learned
  - b. Systematic plan to identify and assess each potentially vulnerable component
  - c. Plan to determine overall system transportation requirements
    - i. Maximum shock loads in all directions
    - ii. Environmental exposure (e.g., temperature extremes and maximum rate of change, etc.)
    - iii. Dangerous vibration frequency bands
  - d. Plan to design and implement a transportation system/method that can meet the agreed upon specification for the transported device reliably, including review and team-internal approvals
  - e. Requirements covering all aspects of the transportation
  - f. System validation program including inspections, examinations, and tests performed prior to transport and after delivery.

In the case that responsibility for some or all the scope of transportation falls outside of FNAL (e.g., a vendor/partner is responsible for transportation/delivery), the Equipment Transportation Plan will clearly define the roles and responsibilities of vendors/partners.

### **5.3 MSS Transportation Panel Recommendation Process**

Any transport qualifying as a Critical Transport per the assessment in Section 5.1 is subject to the MSS Transportation Panel's oversight and recommendation. The documentation described in Section 5.2 provides the core of information used by the MSS Transportation Panel to assess a Critical Transportation. As soon as this assessment has been completed and deemed to be a Critical Transport, this documentation should be drafted and presented to the MSS Transportation Panel. The MSS Transportation Panel workflow is as follows:

- Initial assessment of documentation and discussions with Lead Engineer or designee
- Definition of Transportation Milestones where the MSS Transportation Panel deems it necessary to assess transport preparations (Section 5.3.1)
- When a designated milestone is imminent, the Lead Engineer or designee will inform the MSS Transportation Panel and provide them with the required documentation for that milestone; upon assessment of the provided documentation and any follow-up discussions with the Lead Engineer, the MSS Transportation Panel will issue a Recommendation to Proceed or Not Proceed and the reason for the stated action (Section 5.3.2)
- This process is repeated for each milestone until the transport is completed. (Section 5.3.3)

### 5.3.1. Definition of Transportation Milestones

The first meeting with the MSS Transportation Panel will center around an assessment of the Prevention through Design table, TFMEA, and preliminary Transportation Plan provided. From this documentation, the Transportation Milestones will be defined. These milestones will be the major decision points in the transportation process where the MSS Transportation Panel will deem it necessary to exercise its advisory responsibility. Once defined, these milestones will be documented and managed by the Panel.

*Note: Transportation Milestones are distinct and not necessarily related to Project Milestones.*

Examples of potential Transportation Milestones:

- Prior to first shipment of completed components or subassemblies
- Prior to shipment of subassemblies or components in a different or unusual configuration
- At a critical stage of transportation testing, after significant validation testing is completed but prior to a major escalation of risk (e.g., first test of real device at highway speed or first drop testing with real device).

Examples of events that will typically NOT be Transportation Milestones:

- Successful procurement/fabrication of transportation hardware
- Successful completion of intermediate transportation validation testing
- Completion of design reviews for device to be transported.

Generally, each type of device is expected to have one significant Transportation Milestone. Particularly complex or high-risk transports may have two to three Milestones. Two examples:

- A project is building and shipping 100 pieces of a complex detector component from FNAL to another lab. Each shipment will include 4 components in a container about 1 m<sup>3</sup> and will be done by dedicated hauler. They plan to do some bench testing and do a test shipment of 4 prototype components before production starts in earnest. This project will likely have only one Transportation Milestone: after the end of the test shipment, when the data is analyzed. The loss of the test shipment does not represent a serious/critical risk to the project, so the Transportation Milestone is after this shipment, but prior to start of regular shipments.
- Another project is building 5 pieces of several ton, tractor-trailer sized cryo vessels on-site at FNAL, partially assembled in one building, then moved on-site to a different building on-site for final assembly, and finally moved to the final location for installation. The partially and totally assembled vessels are significantly mechanically different. This project will likely have two Transportation Milestones, one prior to first shipment to the intermediate location and one prior to the first shipment to the final location. The two transports are likely distinct enough to represent significantly different risks, and the Transportation Milestones are prior to the first transports because the risk of damage or loss of even one transport represents a serious risk to the project.





While the date of each Transportation Milestone will be subject to the schedule of the individual project, the stage of the technical process represented by each Transportation Milestone will be defined clearly by the Lead Engineer working with the MSS Transportation Panel.

Each Transportation Milestone will result in a clear and timely MSS Transportation Panel recommendation to proceed or not to proceed. The requirements and expectations that the MSS Transportation Panel will set for a positive recommendation to ship at each milestone will be clearly set forth when the list of milestones is defined. This list of deliverables will be highly specific to the transportation and device and may include, but is not limited to:

- Reviewed and released drawings of transportation hardware
- Reviewed and documented analyses, measurements, and validations testing sufficient to ensure vulnerabilities of transport are understood
- Updated risk and safety documentation sufficient to give confidence that Safety and Quality best practices are being considered (Prevention through Design tables, Transportation Failure Mode and Effect Analysis, etc.)
- Transportation execution documentation commensurate with transportation complexity (instrumentation plan, assembly travelers/procedures, acceptance plans, etc.).

The complexity of the documentation deliverables is expected to scale reasonably with complexity of transport. This includes the level of review expected, from approval by lead engineer to full technical review by external experts.

The Transportation Plan is expected to be a living document, updated as the system design proceeds. Major changes to the Transportation Plan should trigger a follow-up meeting with the MSS Transportation Panel to potentially adjust/update the list of Transportation Milestones and attendant deliverables.

An incomplete or immature Transportation Plan may mean that the MSS Transportation Panel is unable to create an actionable set of milestones. In this case, the Panel will set further expectations for a mature Transportation Plan.

### **5.3.2. Transportation Milestone Review**

At each Transportation Milestone, it is expected that the MSS Transportation Panel will be informed by the Lead Engineer or designee and a meeting may be scheduled. Previously agreed on documentation shall be provided and assessed by the MSS Transportation Panel.

- If the documentation is sufficient, the Panel will provide a Recommendation to proceed to the next milestone.
- If the documentation is incomplete or insufficient, the MSS Transportation Panel will request clarification or additional information/documentation.
- If the documentation remains insufficient, or insufficient time is provided for clear review, the MSS Transportation Panel will provide a Recommendation to Not Transport to the relevant D/S/P Head.

- A Recommendation to Not Transport can be reconsidered upon request by the Lead Engineer in light of additional documentation/information
- Transportations that fall under the review of the MSS Transportation Panel that have received a Recommendation to Not Transport should not be shipped without further evaluation and risk mitigation efforts.

### **5.3.3. Ongoing Repetitive Transports**

Repetitive transports may fall under the recommendation of the first review, determined on a case-by-case basis. In consultation with the Lead Engineer, it is possible that repeated transports will be provisionally recommended to proceed by the MSS Transportation Panel without documentation review if an established, approved, and successful transportation is to be repeated without major differences. Once the final transportation milestone has been closed, the transportation is considered completed.

The Transport Panel will keep an active record of ongoing repetitive transports with standing approval from the panel. The Panel may request periodic updates on transports with standing approval as necessary.

Upon request of the D/S/P Head, standard/routine transportation of devices that might ordinarily be individually considered a Critical Transport can be collectively approved in a well-defined configuration on an ongoing basis (e.g. ILC-style SRF cavities shipped between FNAL and ANL).

A Lessons-Learned process for transportation will be completed and stored electronically to benefit future transports including documentation in the Lab Lessons Learned database.

### **5.3.4. Post Transportation Report**

After completion of a final transportation milestone, or on a periodic basis for transports with standing approval, it is expected that a summary of the transport and data generated will be presented to the Panel for inclusion in the Technical Appendices. This Report should include the following:

- Summary of shipping data that was generated including vibrational and environmental logs
- Lessons learned from transport including design, process, and logistical factors including outgoing/incoming acceptance and validation testing
- Description of any significant failures during transport with root cause analysis.

## 6.0 CRITICAL TRANSPORT PLAN CONTENT

The following is a list of required information to be included in a Transportation Plan provided to the Panel:

- Teamcenter document number (for transportation documentation)
- Date of plan preparation
- Planned date of shipment
- Part number of assembly being moved
- Part number of assembly with shipping supports
- Lead engineer - plan prepared by
- Estimated value of entire shipment
- Risk assessment score
- Most sensitive component(s)
- Weight of shipment
- Weight rating of carrier
- Origin Destination
- Summary list of referenced documentation either existing (including title and document number) or to be created not directly attached as a dataset to the Engineering Note in Teamcenter. Potential examples include work plans, travelers, HAs, MMRs, training, inspection procedures, testing procedures, acceptance criteria
- Specific restrictions (only important, for example “DO NOT FORKLIFT”)
- All applicable modes of transportations (air, rail, road, sea)
- Reviewers – checkers in Teamcenter
- D/S head/management - designee – approver in Teamcenter

## 7.0 TRANSPORT DOCUMENTATION AND RECORD RETENTION

All documentation associated with the transportation plan shall be stored in Teamcenter in an engineering note using the process below:

1. A New Item shall be created in Teamcenter with the type chosen as Engineering Note
  - a. The New Item Name shall use the Transportation Plan prefix followed by a meaningful Name which briefly describes the contents of the note
  - b. A full Description shall be entered for the New Item
2. The appropriate Engineering Note category of Equipment Transport Plan shall be chosen
3. The Revision Author, Revision Comments, Lab Location Code (FIMS #), Exceptional Status, and Division/Section/Project shall be entered
4. The Engineering Note and supporting files shall be added as Data Sets. All documentation required for independent review of the Engineering Note must be included.
5. Approval
  - a. The Teamcenter Review and Approval Workflow should be used to electronically obtain the required approvals and release the Engineering Note.

6. Amendments to existing Engineering Notes shall be entered as a Revision to the original Item in Teamcenter.

The material move request form (MMR) will include a section to confirm transport planning per this chapter has been conducted. Material move requests are stored in the ServiceNow application and are not required to be kept in the transportation plan documentation.

## **8.0 10300 Equipment Transport Technical Appendix**

A technical appendix has been built and is actively maintained to provide an active knowledge base for complex transport at the lab including:

- Engineering process as applied to transport of equipment
- Examples of transport documentation including FMEAs, Transport Plans, PtD Tables, requirements, and specifications, etc.
- Technical guidance on common techniques used during device design for transportation and transport support system design
- Examples and guidance on transportation execution including logistics, transport vendor procurement, instrumentation, etc.
- Lessons learned summaries from previous transports with references to supporting documentation.