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# EC TRANSMISSION LINE RISK IDENTIFICATION AND MITIGATION ANALYSIS

March 2012

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# EC Transmission Line Risk Identification and Mitigation Analysis

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# EC Transmission Line Risk Identification and Analysis

March 2012

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# REVISION RECORD

| Revision | Date | Description of Changes |
|---|---|---|
| 00 | 3/9/2012 | Original |

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# 1 PURPOSE AND SCOPE

The purpose of this document is to assist in evaluating and planning for the cost, schedule, and technical project risks associated with the delivery and operation of the EC (Electron cyclotron) transmission line system. In general, the major risks that are anticipated to be encountered during the project delivery phase associated with the implementation of the Procurement Arrangement [1] for the EC transmission line system are associated with:

(1) Undefined or changing requirements (e.g., functional or regulatory requirements)
(2) Underperformance of prototype, first unit, or production components during testing
(3) Unavailability of qualified vendors for critical components

Technical risks associated with the design and operation of the system are also identified.

# 2 RISK IDENTIFICATION AND QUALIFICATION

## 2.1 Risk Identification

Risk is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective. Risk is an inherent part of all activities, whether the activity is simple and small, or large and complex. The relative size and/or complexity of an activity may or may not be an indicator of the potential degree of risk associated with that activity.

There are two main sources of risks that can affect the ITER Project: (1) Event risks, and (2) Uncertainty risks. Both types of risks are covered in this document.

Event Risks are potential occurrences that can have an impact on project scope, increase project cost and/or schedule, reduce safety margins, or reduce the quality of the final product. Event Risks can be caused both internally and externally and, in many cases, can be foreseen by project management within some reasonable planning horizon. Examples of foreseeable events might include instabilities in qualified craft labor at a construction site, or the ability of component suppliers to meet their delivery schedules. Event risks are typically stated in the following manner: "As result of ..........................., there is a risk that...................., resulting in..........................."

Event Risks include the following categories:

- Technical
  - Design
  - Safety
  - Environment
  - Technology
  - Interfaces

- Programmatic
  - Sequencing
  - Delays in procurement
  - Delays in delivery of equipment
  - Non availability of buildings in time for science

Uncertainty risks are the result of variability of the estimating data used to create the project baseline cost and schedule estimates. This primarily covers uncertainties in project cost and schedule estimates that result from:

- Errors and omissions
- Inflation
- Adverse weather
- Pricing variances
- Quantity variances
- Complexity
- Facility access

## 2.2 Risk Quantification

Risk quantification involves assessing risks to determine potential project consequences. This consists of determining the likelihood of the identified risk actually occurring, assessing the impact if it does occur, and then assigning an overall rating to the risk. The guidelines for use of the ITER Project risk assessment matrix are given in [2], and restated below.

### *2.2.1 Determining Likelihood*

Risks are categorized by likelihood or probability of occurrence. Generally, a risk that is determined to be in the "Very Likely" to occur category is one that has a probability of 80% or greater of occurrence. A risk that is "Likely" to occur is one that has a probability between 40%–80%. A risk that has less than a 40% chance of occurring is categorized as "Unlikely." The probability categories are summarized in Table 2.1.

**Table 2.1. Probability of Occurrence Matrix**

| **Probability of Occurrence** | | **Criteria** |
|---|---|---|
| **Qualitative** | **Quantitative** | |
| Very Likely (5) | >0.8 | The probability of occurrence in the life of the project is judged to be greater than 80%. |
| Likely (4) | >0.4 but <0.8 | The probability of occurrence in the life of the project is judged to be greater than 40% but less than 80%. |
| Unlikely (3) | >0.1 but <0.4 | The probability of occurrence in the life of the project is judged to be greater than 10% but less than 40%. |
| Very Unlikely (2) | >0.01 but <0.1 | The probability of occurrence in the life of the project is judged to be greater than 1% but less than 10%. |
| Not Credible (1) | <0.01 | The probability of occurrence in the life of the project is judged to be less than 1%. |

### *2.2.2 Determining Impact*

Risks can also have varying impacts/consequences on the project. If a risk occurs, a negative consequence usually results. The consequence will typically adversely affect the technical accomplishment, result in a schedule or milestone slip, and/or cause a cost impact. The degree of the consequence is measured. Table 2.2 is used in making the determination of the impact to the project.

**Table 2.2. Risk Impact Matrix**

| Consequence Category | Cost: Impact on project contingency | Schedule: IPS-ITER Integrated Project Schedule | Technical: Impact on performance |
|---|---|---|---|
| Negligible (1) | There is negligible change in Construction or life-cycle cost (i.e., < 1% of Negotiated kIUA). <0.01 | The effects of this risk would only be felt by activities not near the Critical Path, and the impacts are mitigated below Level 3 milestones. Schedule impacts can be covered with available float. | Negligible degradation, performance falls below upper end of goal; project goals can still be met. |
| Marginal (2) | There is a marginal impact in Construction or life-cycle cost between 1 - 10% of Negotiated kIUA. Costs marginally exceed budget. >0.01 but <0.1 | Activities on the Critical Path and IO Milestones are NOT affected, but activities near the Critical Path or Level 3 milestones could be affected. (>1 week to 1 Month) | Marginal performance shortfall, but workarounds available; risks might impact project goals if not mitigated. |
| Significant (3) | Cost estimates significantly exceed budget. There is a potential for a >10% kIUA impact of a procurement arrangement allocation budget or cost change (i.e., either increase or decrease) in the Construction or lifecycle cost of an individual subsystem. > 0.1 but <0.2 | Any impact to an IO Milestone (Level 2). >1 Months delay in delivery of an item ON the project's Critical Path, or > 1-3 Months of the time allocated to an activity NEAR the Critical Path. | Significant degradation in modification/project technical performance. Significant threat to facility mission, environment or people, requires some equipment redesign or repair, significant environmental remediation or causes injury requiring medical treatment. Project goals may not be met (essential performance parameter not met). |
| Critical (4) | Cost estimates seriously exceed the budget. There is a potential for a >20% kIUA impact of a procurement arrangement allocation budget or cost change (i.e., either increase or decrease) in the Construction or lifecycle cost of an individual subsystem. >0.2 but <0.4 | Any impact to an IO Milestone (Level 1). > 3 Months delay in delivery of an item ON the project's Critical Path, or > 3-6 months of the time allocated to an activity NEAR the Critical Path. | Serious threat to facility mission, environment, or people, possibly completing only portions of the mission or requiring major equipment redesign or rebuilding, extensive environmental remediation or intensive medical care for life-threatening injury. |
| Crisis (5) | Cost estimates unacceptably exceed the budget. There is a potential for a >40% kIUA impact of a procurement arrangement allocation budget or cost change (i.e., either increase or decrease) in the Construction or lifecycle cost of an individual subsystem. >0.4 | Any impact to an IO Milestone (Level 0). > 6 Months delay in delivery of an item ON the project's Critical Path. | Catastrophic threat to facility(s), mission, environment, or people, possibly causing loss of mission, long-term environmental abandonment and/or death. |

### *2.2.3 Overall Risk Rating*

A risk's probability must be weighed against its potential impact in order to assess the action necessary for dealing with the risk. A risk that has a high probability of occurrence can have a negligible impact on the project. Conversely, a low probability risk can have a high impact on the project's technical accomplishment, schedule, or cost. Each project risk is assigned an overall risk rating as Low, Medium, High, or Very High based on the likelihood of occurrence and consequences. Table 2.3 relates the overall risk ranking with the required action.

**Table 2.3. Overall Risk Ranking vs Action**

| Level | Action |
|---|---|
| Low | Risk is included in the risk file and reviewed by DA TRO concerned.<br>Actions are evaluated in order to reduce the risk.<br>Any escalation is reported to the DDG, or DA Head. |
| Medium | A technical owner is appointed to monitor the risk evolution and report to the DA TRO and the RO concerned.<br>Actions are evaluated in order to reduce the risk. |
| High | Same as level MEDIUM plus definition of specific mitigation actions.<br>These actions are defined by the DA TRO (or DDG if a Project-level type risk) concerned with the risk, who identifies possible trigger events to start them.<br>The owner monitors the risks and these trigger events. |
| Very High | The risk owner is the DA TRO (as designated directly by the DA Head), who closely monitors the effectiveness of the mitigation actions at each project review meeting. These risks require close IO monitoring. These risks also require the identification of a mitigation strategy (recorded on the risk register), and regular review at project management meetings and IO-DA meetings.<br>Frequent high-level visibility of these risks is required. Elimination and/or mitigation of risks rated as "Very High" overall is a priority.<br>Planned mitigation actions are started as scheduled. |

### *2.2.4 Risk Assessment Matrix*

The ITER Project employs an established risk methodology for consistency and quality in the risk management process, as represented by the risk assessment matrix shown in Table 2.4. The y-axis determination (Likelihood of occurrence) is first made for an identified risk, followed by the x-Axis (Impact/Consequence). The table then yields an "overall risk rating."

**Table 2.4. Risk Assessment Matrix**

| **Risk Assessment Matrix – Assigning an Overall Risk Rating** | | | | | |
|---|---|---|---|---|---|
| **Likelihood of Occurrence** | **Baseline Impact/Consequence** | | | | |
| | **Negligible (1)** | **Marginal (2)** | **Significant (3)** | **Critical (4)** | **Crisis (5)** |
| Very likely (5) | High | High | Very High | Very High | Very High |
| Likely (4) | Medium | High | High | Very High | Very High |
| Unlikely (3) | Medium | Medium | High | High | Very High |
| Very Unlikely (2) | Low | Medium | Medium | High | High |
| Not Credible (1) | Low | Low | Medium | Medium | High |

## 3 LISTING OF PROJECT RISKS ASSOCIATED WITH EC TRANSMISSION LINE

Table 3.1 identifies and evaluates EC transmission line project, design, manufacturing, operational, and functional risks [3].

# Table 3.1. EC Transmission Line Risks

## Project Risks

| Risk Analysis and Mitigation Form | | | | Title: EC Transmission Line risk log | | | | | Procurement Arrangement: ECH PA 5.2.P2.US.01.0 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Responsible Manager: Gandini | | | | | | | | | | | | | | | | | |
| | | | | | Revision Number: | | | 0 | Date: January 2012 | | | | | | | | |
| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | | |
| WBS Number | Component / Organization | Procurement Package | Risk Owner | Description of Risk | Likelihood of Occurrence | Impact | | Overall Risk Rating | Risk Approach | Mitigation Strategy (Required for High Level Risks) | Initiation Date | Completion Date | Likelihood of Occurrence | Impact | | Overall Risk Rating |
| 05.2.1 | CHD | TL | IO / USIPO | If resources required for R&D are not available or are not available on time, then there could be a cost and/or schedule impact. | 2 | Technical | 2 | Medium | Mitigate | Ensure that USIPO resources are sufficient for the duration of the R&D program | | | 2 | Technical | 1 | Medium |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If the functional requirements are ill-defined, substantially changed, or not available, then there could be a cost and/or schedule impact due to redesign and/or rework. | 3 | Technical | 2 | Medium | Mitigate | Rely on design review process and IO documentation (service handbooks) to provide clarification of functional specifications, and codes and standards. | | | 2 | Technical | 2 | Medium |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 2 | |
| 05.2.1 | CHD | TL | IO / USIPO | If main interfaces (i.e., Gyrotron, Cooling water, Vacuum, CODAC) are ill-defined, or are changed during design/manufacture phases, then there could be a cost and/or schedule impact due to redesign and documentation. | 3 | Technical | 2 | Medium | Avoid | Rely on PCR process and interface summit to minimize impacts. | | | 2 | Technical | 2 | Medium |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 2 | |
| 05.2.1 | CHD | TL | IO | If manpower resources are insufficient in IO/ EC to support Transmission Line activities, then there could be a schedule impact. | 3 | Technical | 3 | High | Avoid | Accurate resource estimates based on previous development and installation experience should be developed and allocated to avoid this risk. | | | 2 | Technical | 1 | Low |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 3 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If critical components are available only from single suppliers, then cost and/or schedule could be affected by necessity to identify and/or train alternate suppliers. | 3 | Technical | 2 | Medium | Mitigate | Establish supplier list for all components. Procure prototype components from multiple suppliers during design and testing phases. Develop alternative designs that can be fabricated to print. | | | 2 | Technical | 1 | Low |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO | If spare parts are unavailable, then construction schedules and/or costs may increase or system functionality could be affected. | 3 | Technical | 2 | Medium | Avoid | Perform spare parts assessment and include in revision to PA. May require PCR to correctly track cost increase. | | | 2 | Technical | 1 | Low |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |

# Design Risks

**Risk Analysis and Mitigation Form** **Title: EC Transmission Line risk log** **Procurement Arrangement: ECH PA 5.2.P2.US.01.0**

**Responsible Manager: Gandini**

**Revision Number: 0** **Date: January 2012**

| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WBS Number** | **Component / Organization** | **Procurement Package** | **Risk Owner** | **Description of Risk** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** | **Risk Approach** | **Mitigation Strategy (Required for High Level Risks)** | **Initiation Date** | **Completion Date** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** |
| 05.2.1 | CHD | TL | IO | If qualification requirements for critical components are not defined or not defined in a timely manner, there could be a cost and/or schedule impact due to redesign or rework. | **3** | **Technical** | **2** | **Medium** | **Mitigate** | Expedite PCR process and rely on interface summit to provide timely information. | | | **2** | **Technical** | **2** | **Medium** |
| | | | | | | **Schedule** | **2** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **2** | | | | | | | **Cost** | **2** | |
| 05.2.1 | CHD | TL | IO / USIPO | If R&D of critical components is more expensive/takes longer than planned, then there could be a cost and/or schedule impact. | **4** | **Technical** | **2** | **High** | **Mitigate** | Continuation of prototype testing and use of industry to manufacture these prototypes helps to identify such components and to accurately estimate cost and time. | | | **3** | **Technical** | **1** | **Medium** |
| | | | | | | **Schedule** | **3** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **3** | | | | | | | **Cost** | **2** | |
| 05.2.1 | CHD | TL | IO | If thermal expansion of waveguide on long runs appears excessive due to large fluctuations in building temperature and heating during operation, then excessive mode conversion and efficiency loss would result, and system functionality could be affected. | **3** | **Technical** | **3** | **High** | **Mitigate** | Mitigate by designing sufficient margin on waveguide cooling and designing and including waveguide expansion unit to accommodate axial movement due to thermal expansion. Consider the design of temperature controls on water cooling. | | | **2** | **Technical** | **2** | **Medium** |
| | | | | | | **Schedule** | **2** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **3** | | | | | | | **Cost** | **2** | |
| 05.2.1 | CHD | TL | IO / USIPO | If miter bend mirror cooling is inadequate for 2 MW CW operation, then mirror overheating and distortion would result, and system functionality could be affected. | **3** | **Technical** | **3** | **High** | **Mitigate** | Qualify conservative design with high power testing. Rely on conservative thermal/mechanical modeling underway and perform high power tests at 2 MW with prototype designs using a resonant ring setup on a test stand. | | | **2** | **Technical** | **2** | **Medium** |
| | | | | | | **Schedule** | **2** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **2** | | | | | | | **Cost** | **2** | |
| 05.2.1 | CHD | TL | IO / USIPO | If polarizer miter bend mirror cooling is inadequate for 2 MW CW operation, then mirror overheating and distortion would result, and system functionality could be affected | **4** | **Technical** | **3** | **High** | **Mitigate** | Qualify conservative design with high power testing. Rely on conservative thermal/mechanical modeling underway and perform high power tests at 2 MW with prototype designs using a resonant ring setup on a test stand. | | | **3** | **Technical** | **2** | **Medium** |
| | | | | | | **Schedule** | **2** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **2** | | | | | | | **Cost** | **2** | |

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**Revision Number:** **0** | **Date: January 2012**

| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WBS Number** | **Component / Organization** | **Procurement Package** | **Risk Owner** | **Description of Risk** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** | **Risk Approach** | **Mitigation Strategy (Required for High Level Risks)** | **Initiation Date** | **Completion Date** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** |
| 05.2.1 | CHD | TL | IO / USIPO | If miter bend mirror precision is inadequate for meeting acceptable mode purity performance, then excessive mode conversion and efficiency loss would result, and system functionality could be affected. | **2** | **Technical** | **2** | **Medium** | **Mitigate** | Rely on performance tests and coordinate measurement machine measurements to verify manufacturing capability during prototype phase and to qualify manufacturing processes. | | | **2** | **Technical** | **1** | **Medium** |
| | | | | | | **Schedule** | **2** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **2** | | | | | | | **Cost** | **2** | |
| 05.2. | CHD | TL | IO / USIPO | If waveguide alignment is inadequate for reasonable mode performance required, then excessive mode conversion and efficiency loss would result, and system functionality could be affected. | **3** | **Technical** | **3** | **Medium** | **Mitigate** | Rely on performance tests, measurements, and alignment techniques developed during prototype installation to verify practical alignment accuracy. Perform mechanical analysis of the support structure to analyze alignment stability | | | **2** | **Technical** | **2** | **Medium** |
| | | | | | | **Schedule** | **2** | | | | | | | **Schedule** | **2** | |
| | | | | | | **Cost** | **2** | | | | | | | **Cost** | **2** | |

# Manufacturing Risks

| Risk Analysis and Mitigation Form | Title: EC Transmission Line risk log | Procurement Arrangement: ECH PA 5.2.P2.US.01.0 |
|---|---|---|
| Responsible Manager: Gandini | | |
| | Revision Number: 0 | Date: January 2012 |

| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS Number | Component / Organization | Procurement Package | Risk Owner | Description of Risk | Likelihood of Occurrence | Impact | | Overall Risk Rating | Risk Approach | Mitigation Strategy (Required for High Level Risks) | Initiation Date | Completion Date | Likelihood of Occurrence | Impact | | Overall Risk Rating |
| 05.2.1 | CHD | TL | USIPO / IO | If qualification requirements for critical components are not provided until the manufacturing process, then there could be a cost and/or schedule impact. | 3 | Technical | 3 | High | Mitigate | Expedite PCR process and rely on interface summit to provide timely information. | | | 2 | Technical | 2 | Medium |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 3 | | | | | | | Cost | 2 | |
| 05.2.1 | CHD | TL | USIPO | If the level of testing is insufficiently defined prior to or during manufacturing, then there could be a cost/and or schedule impact. | 3 | Technical | 3 | High | Mitigate | Develop and implement a test program during development stage to ensure that functional requirements are met | | | 1 | Technical | 1 | Low |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 3 | | | | | | | Cost | 2 | |
| 05.2.1 | CHD | TL | USIPO | If completed and approved build-to-print drawings are not available in time for the final design, then there could be a cost and/or schedule impact. | 3 | Technical | 3 | High | Mitigate | Perform prototype testing based on industrial supplied components prior to final design, undergo tender process with sound evaluation process; require drawing completion early in the prototype process. | | | 1 | Technical | 1 | Low |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 3 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | USIPO | If manufacturers are relying on subcomponents from other suppliers that fail to meet requirements then there could be schedule impact | 2 | Technical | 2 | Medium | Mitigate | Sub-component manufacture performed (or strongly monitored) by assembly contractor | | | 1 | Technical | 1 | Low |
| | | | | | | Schedule | 2 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | USIPO | If only a single industry is available for some waveguide components, then there could be a cost and/or schedule impact due to necessity to identify and/or train additional suppliers. | 2 | Technical | 1 | Medium | Mitigate | Procure prototype components from multiple suppliers during design and testing phase prior to final design | | | 1 | Technical | 1 | Low |
| | | | | | | Schedule | 2 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 2 | |
| 05.2.1 | CHD | TL | USIPO | If only a single supplier is available for the waveguide, then there could be a cost and/or schedule impact due to necessity to identify and/or train additional suppliers. | 3 | Technical | 2 | Medium | Mitigate | Develop alternative designs that can be fabricated to print. Procure and test prototype of final design prior to launching bid. | | | 1 | Technical | 1 | Low |
| | | | | | | Schedule | 2 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 2 | |

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**Revision Number: 0** **Date: January 2012**

| Risk Identification & Evaluation | | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS Number | Component / Organization | Procurement Package | Risk Owner | Description of Risk | Likelihood of Occurrence | Impact | | Overall Risk Rating | Risk Approach | Mitigation Strategy (Required for High Level Risks) | Initiation Date | Completion Date | Likelihood of Occurrence | Impact | | Overall Risk Rating |
| 05.2.1 | CHD | TL | USIPO | If waveguide joint accuracy is not adequate to ensure performance,, then there could be vacuum leaks, excessive mode conversion, and efficiency loss. | 4 | Technical<br>Schedule<br>Cost | 3<br>2<br>2 | High | Mitigate | Reduce number of joints in TL. Perform testing to identify accuracy requirements necessary to achieve performance, and determine whether/how they can be achieved. Perform prototype tests and joint development to qualify and provide feedback to improve the design. Analyze merits of multiple designs. | | | 2 | Technical<br>Schedule<br>Cost | 1<br>1<br>2 | Medium |
| 05.2.1 | CHD | TL | IO / USIPO | If miter bend mirror precision is inadequate for meeting acceptable mode purity performance, then there could be excessive mode conversion and efficiency loss. | 4 | Technical<br>Schedule<br>Cost | 2<br>2<br>2 | High | Mitigate | Rely on performance tests and coordinate measurement machine measurements to verify manufacturing capability during prototype phase. | | | 2 | Technical<br>Schedule<br>Cost | 2<br>2<br>2 | Medium |
| 05.2.1 | CHD | TL | IO / USIPO | If waveguide straightness and alignment is inadequate, then there could be excessive mode conversion and efficiency loss. | 4 | Technical<br>Schedule<br>Cost | 2<br>2<br>2 | High | Mitigate | Rely on performance tests, measurements, and alignment techniques during prototype installation to verify practical alignment accuracy. | | | 2 | Technical<br>Schedule<br>Cost | 2<br>2<br>2 | Medium |

# Operational Risks

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**Responsible Manager: Gandini**

**Revision Number:** 0 **Date: January 2012**

| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS Number | Component / Organization | Procurement Package | Risk Owner | Description of Risk | Likelihood of Occurrence | Impact | | Overall Risk Rating | Risk Approach | Mitigation Strategy (Required for High Level Risks) | Initiation Date | Completion Date | Likelihood of Occurrence | Impact | | Overall Risk Rating |
| 05.2.1 | CHD | TL | IO | If the EC_TL cooling circuit leaks frequently then complicated maintenance issues could result due to the large number of cooling circuit joints. | 3 | Technical | 1 | High | Mitigate | Design cooling system joints for long-term reliability– prototypes of critical parts -; minimize use of plastic lines and non-metallic seals; test reliability under actual conditions with a large number of cooling water on/off cycles | | | 2 | Technical | 1 | Medium |
| | | | | | | Schedule | 2 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO | If vacuum seals fail at unacceptably high rate, causing a vacuum leak in the waveguide, an operational reliability issue results and system availability goals may not be met | 3 | Technical | 1 | High | Mitigate | Reliability of all-metal vacuum seals minimizes risk. Vacuum interlocks prevent operation with significant loss of vacuum. Test stand vacuum system tests after repeated thermal cycles will help to establish design reliability. | | | 2 | Technical | 1 | Low |
| | | | | | | Schedule | 3 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If Tritium leaks into a transmission line due to a window crack or braze flaw, then system availability is impacted and significant operational costs incurred. | 3 | Technical | 1 | Medium | Accept | A tritium clean up plan needs to be established and demonstrated on a test stand (without tritium) and at tritium test stands on mock-up components. Isolate line; cleanup with baking; verify that ferrofluidic feedthroughs are acceptable. | | | 3 | Technical | 1 | Medium |
| | | | | | | Schedule | 2 | | | | | | | Schedule | 2 | |
| | | | | | | Cost | 2 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If there is a vacuum leak in a transmission line, then system functionality could be affected. | 3 | Technical | 1 | Medium | Accept | The transmission line must be designed to facilitate disassembly and repair techniques. Demonstrations of removal of various components from the system and re-assembly must be performed on test stands and other mock-ups. | | | 3 | Technical | 1 | Medium |
| | | | | | | Schedule | 1 | | | | | | | Schedule | 1 | |
| | | | | | | Cost | 1 | | | | | | | Cost | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If plastic deformation of waveguides occurs during a seismic event, then excessive down time might result when getting the ECH system back online | 1 | Technical | 1 | Low | Mitigate | Design structures to accommodate seismic events. Plan for adequate spare parts for potential damage to waveguide. | | | 1 | Cost | 1 | Low |
| | | | | | | Schedule | 2 | | | | | | | Technical | 1 | |
| | | | | | | Cost | 1 | | | | | | | Schedule | 1 | |
| 05.2.1 | CHD | TL | IO | If loss of mode purity due to mis-alignment or thermal expansion occurs, then system performance will suffer low efficiency and reduced launcher beam quality | 2 | Technical | 2 | Medium | Mitigate | Design supports to accommodate thermal expansion; Investigate and develop a built-in mode purity monitor using mode selective directional coupler. Consider adding a mode filter to launcher. | | | 1 | Cost | 1 | Low |
| | | | | | | Schedule | 1 | | | | | | | Technical | 2 | |
| | | | | | | Cost | 1 | | | | | | | Schedule | 1 | |

**Risk Analysis and Mitigation Form** **Title: EC Transmission Line risk log** **Procurement Arrangement: ECH PA 5.2.P2.US.01.0**

**Responsible Manager: Gandini**

**Revision Number: 0** **Date: January 2012**

| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WBS Number** | **Component / Organization** | **Procurement Package** | **Risk Owner** | **Description of Risk** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** | **Risk Approach** | **Mitigation Strategy (Required for High Level Risks)** | **Initiation Date** | **Completion Date** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** |
| 05.2.1 | CHD | TL | IO / USIPO | If a bellows fails in a seismic break, then waveguide vacuum loss and potential operations down time will result | 2 | **Technical** | 2 | **Medium** | **Mitigate** | Dedicated R&D: fatigue test – individual bellows tests – continuous vacuum measurement for early detection of performance deterioration mechanical end-stops for mirror. Plan on at least one spare seismic break | | | 1 | **Technical** | 1 | **Low** |
| | | | | | | **Schedule** | 2 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | USIPO | If a bellows fails in an expansion section, then waveguide vacuum loss and potential operations down time will result | 2 | **Technical** | 2 | **Medium** | **Mitigate** | Dedicated R&D: fatigue test – individual bellows tests – continuous vacuum measurement for early detection of performance deterioration – mechanical end-stops for mirror. Plan on at least one spare bellows expansion unit | | | 1 | **Technical** | 1 | **Low** |
| | | | | | | **Schedule** | 2 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If there is a failure in control system components or sensors, then operations will be impacted | 2 | **Technical** | 3 | **Medium** | **Mitigate** | Divide control system into 4 subgroups that are not co-located to provide "graceful degradation. Maintain adequate spare part inventories. Use standard instrumentation parts common with other systems | | | 1 | **Technical** | 2 | **Low** |
| | | | | | | **Schedule** | 2 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If stray radiation is excessive at a DC break or other locations, then safety of operations personnel may be impacted | 2 | **Technical** | 2 | **Medium** | **Mitigate** | Add shielding based on calculations and later measurements using realistic prototypes. Initially and periodically restrict personnel access to all waveguides under operation until microwave leakage checks have been performed. | | | 2 | **Technical** | 1 | **Low** |
| | | | | | | **Schedule** | 2 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If the mode purity of beams delivered to launcher is below requirements, then radiated beam quality will be inadequate and system efficiency will be below acceptable levels. | 2 | **Technical** | 2 | **Medium** | **Avoid** | Close contact with gyrotron and transmission line experts should be maintained during the development process. Develop a strategy to test transmission line mode purity and gyrotron beam alignment. Improve alignment. | | | 1 | **Technical** | 1 | **Low** |
| | | | | | | **Schedule** | 1 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 2 | | | | | | | **Cost** | 1 | |

# Functional Risks

**Risk Analysis and Mitigation Form** **Title: EC Transmission Line risk log** **Procurement Arrangement: ECH PA 5.2.P2.US.01.0**

**Responsible Manager: Gandini**

**Revision Number: 0** **Date: January 2012**

| Risk Identification & Evaluation | | | | | | | | | Risk Disposition | | | | Risk Rating After Mitigation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WBS Number** | **Component / Organization** | **Procurement Package** | **Risk Owner** | **Description of Risk** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** | **Risk Approach** | **Mitigation Strategy (Required for High Level Risks)** | **Initiation Date** | **Completion Date** | **Likelihood of Occurrence** | **Impact** | | **Overall Risk Rating** |
| 05.2.1 | CHD | TL | IO / USIPO | If misalignment of transmission line occurs, then the condition may not be detected and the system performance may be degraded below specifications and launcher beam quality will be affected. | 2 | **Technical** | 2 | **Medium** | **Mitigate** | Perform pre-installation and in-situ alignment tests using in-line laser. Develop periodic alignment check scheme. Develop and install a mode selective directional coupler. | | | 1 | **Technical** | 1 | **Low** |
| | | | | | | **Schedule** | 2 | | | | | | | **Schedule** | 2 | |
| | | | | | | **Cost** | 2 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If polarization control is inadequate or lost, then efficient coupling to the plasma will be reduced and system mission affected | 2 | **Technical** | 2 | **Medium** | **Mitigate** | Monitor polarization delivered to plasma using diagnostics and initial low power testing Develop back-up method for verifying polarizer groove position and polarization rotation through the waveguide system. Develop and install a mode selective polarization sensitive directional coupler. | | | 1 | **Technical** | 2 | **Low** |
| | | | | | | **Schedule** | 1 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | IO / USIPO | If transmission efficiency is degraded, then the condition may not be known and the system performance will be below specifications. | 2 | **Technical** | 2 | **Medium** | **Mitigate** | Monitor power delivered via diagnostics. Develop a thermal based power monitor for relative comparison to baseline operations. | | | 1 | **Technical** | 2 | **Low** |
| | | | | | | **Schedule** | 1 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 2 | |
| 05.2.1 | CHD | TL | IO | If total power is degraded due to failure of an subsystem (e.g., vacuum, gyrotron TL component, control system), then system performance will be below specification | 4 | **Technical** | 1 | **Medium** | **Accept** | Analyze effects of failures in other systems on transmission line performance. Maintain spares; design for TL redundancy. | | | 4 | **Technical** | 1 | **Medium** |
| | | | | | | **Schedule** | 1 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |
| 05.2.1 | CHD | TL | IO | If the mode purity from the gyrotron or the coupling into the HE_11 waveguide generates a non-negligible percentage of higher order modes, then system performance will be below specification and launch beam quality affected. | 3 | **Technical** | 3 | **High** | **Mitigate** | Require stringent mode purity coupling into waveguide, develop mode purity monitors, turn-off beam lines with high mode impurity | | | 1 | **Technical** | 2 | **Low** |
| | | | | | | **Schedule** | 2 | | | | | | | **Schedule** | 1 | |
| | | | | | | **Cost** | 1 | | | | | | | **Cost** | 1 | |

# 4 REFERENCES

[1] Procurement Arrangement 5.2.P2.US.01.0 ITER_D_2UY9XB
[2] Risk Management Plan (RMP) ITER_D_22F4LE v 2.0
[3] Risk Identification and Analysis Template ITER_D_2DLTYX_v1_1