# STORM Team
# Mission Day Instructions

## Overview

The STORM Team monitors solar activity. You will track X-rays and protons from the sun. Solar proton events are dangerous. Intense and excessive electromagnetic energy and radioactive protons can cause great harm to the astronauts and damage the space station. You will monitor X-ray production, which provides an indicator of a possible SPE. X-rays are produced when the sun's activity increases and protons move from low energy states to high-energy states. High levels of X-rays may indicate that an SPE is imminent. X-ray activity can also impact the radio and navigation functions of the space station.

As a member of the STORM team, you will receive X-ray and proton data from the GOES-8 (Geostationary Orbiting Environmental Satellite-8). Once the data is received, it is your team's responsibility to record this data, graph it, and make calculations. You must predict the strength of the storm as well as how long it might last. It will be the duty of your Crisis Management team representative to communicate what you learn to all other teams. You will need to make recommendations to protect the space station and the crew. Remember, your work is vital to the space station and the astronauts on board.

### Your Task

First, review the information that you studied during specialist training. This information may be found at http://www.wju.edu/clc/ssa . Study your notes on solar weather-- especially the information on sunspots, coronal mass ejections, and solar proton events. Review the events that occurred during earlier storms when the space station encountered minor emergencies due to a coronal mass ejection.

Second, use your training to analyze data, make calculations, graph it, and make recommendations. You must monitor all changes in the solar weather patterns and report any noteworthy fluctuations to the rest of the teams. It is critical that X-ray and proton levels are closely watched because they can have immediate effects on the space station crew.

Before the mission begins, you should be able to answer the following questions:

1. What solar events are potentially dangerous? How are these events monitored?
2. What does a sudden spike in X-rays indicate?
3. What is a Coronal Mass Ejection?
4. How can you tell if a Coronal Mass Ejection (CME) is likely to occur?
5. What is a Solar Proton Event (SPE)?
6. Why does the proton data need to be closely monitored by the ISS astronauts?

## Mission Day Materials

On mission day it will be critical to be prepared to assist the Space Station crew if it becomes necessary. To do this effectively your team will need the following:

- One computer to receive real-time solar weather data from the GOES-8 satellite
- One or more copies of the Space Station Reference guide
- Mission Day Materials packet (one per team member):
  - Mission Day Instructions
  - STORM Team Data Tracking Tables
  - STORM Team Data Graphs
- 15 Blank Report Forms (see Mission Day Materials packet) on colored paper to deliver to the Communications Team
- Calculators for each team member
- Rulers for plotting data on graphs
- Ballpoint pens or pencils of various colors (optional)

## Job Assignments

The following tasks must be completed during the mission. Next to each task, assign a team member or members.

| Team Member(s) Assigned To This Task | Task |
|---|---|
| _____ | **Data Recording**: Monitors real-time data for new readings and bulletins from mission control. The URL for the real-time data will be given by Mission Control at the start of the mission. This may be combined with other tasks. |
| _____ | **Data Analysis (X-Ray Production)**: Records real-time data in data tracking tables. Conducts analyses using data tracking worksheet. Completes Report Forms every five to six minutes or as needed. |
| _____ | **Data Analysis (Proton Production)**: Records real-time data in data tracking tables. Conducts analyses using data tracking worksheet. Completes Report Forms every five to six minutes or as needed. |
| _____ | **Data Graphing**: Records real-time data and projections on graphs. Uses ruler to make predictions. This may be combined with Data Analysis tasks. |
| _____ | **Crisis Management**: Makes sure all data is analyzed every five to six minutes. Determines priority level, whether there are any concerns, and helps team decide on any recommendations. Takes this information to the Crisis Management Team for further discussion. |
| _____ | **Data Runner**: Gathers report forms every five to six minutes. Prioritizes any urgent recommendations. May be combined with Crisis Management Tasks. |
| _____ | **Research and Reference**: Assists team in finding necessary information to make recommendations to Mission Control. Reads and understands information provided in the Reference Guide. May be combined with other tasks above. |
| _____ | **Reporter**: Assists team in recording the situation as the mission progresses. Tracks emergencies, options, choices, successes, and areas for improvement. |

# STORM Team— Data Tracking Instructions

You will be receiving readings every five to six minutes from the GOES-8 Satellite in orbit between the Earth and the Sun. The data will have information on X-Ray and Proton production from the sun. It is imperative that your team is familiar with the data and that you are able to analyze it quickly and efficiently.

Using the instructions below and the attached spreadsheet, you should be able to conduct all the necessary calculations. Note: Since we are working with large numbers here, there is no need to use decimals-- round to the **nearest whole number**.

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*First, find the two spreadsheets labeled "STORM Team Data Tracking Table" (One is for X-rays and the other for Protons)*

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Enter the date given by the GOES-8 at the top of the page.

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Column A: Coordinated Universal Time (UTC)
The time will be included in the data from the GOES-8. Record the time in UTC units in Column A.

Time is given in Coordinated Universal Time (UTC), a universal standard. To eliminate any errors, we use a 24-hour clock with no "am" or "pm". On a 24-hour clock, 00:00 or 24:00 is midnight and 12:00 is noon. 23:59 is one minute before midnight. One o'clock in the morning is 01:00. Four-twenty in the afternoon is 16:20, etc.

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Column B: Real-Time Data
Record the real-time data in Column B. You will also need to plot this data on a graph.

**With X-Rays**: Energy is measured in microwatts, which is 1/1000 of a watt. A nightlight is about 5 watts. When we deal with X-rays, we begin to see impacts at one ten millionth of the nightlight's power.

**With Protons**: Protons of an energy level exceeding 10 MeV (mega electron volts) are counted. The unit of measure is the number of protons hitting the measuring device on the satellite.

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Column C and D: Categorizing
Take the data from Column B and determine where that number falls in the ranges given in the table below. Record the corresponding Category in Column C and Descriptor in Column D.

| X-Ray Amount (microwatts) | **X-ray Category** | Descriptor |
|---|---|---|
| 0 –50 | R1 | Minor |
| 50-100 | R2 | Moderate |
| 100-1000 | R3 | Strong |
| 1000-2000 | R4 | Severe |
| >2000 | R5 | Extreme |

| Proton Production | **Proton Production Category** | Descriptor |
|---|---|---|
| 10-99 | S1 | Minor |
| 100-999 | S2 | Moderate |
| 1000-9999 | S3 | Strong |
| 10,000-99,999 | S4 | Severe |
| 100,000+ | S5 | Extreme |

For example, if the X-ray energy is 357 microwatts, this falls in the range from 100-1000. The category is "R3" and the Descriptor is "Strong".

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Column E: Change in Protons and X-Rays
Calculate the change since the last reading. Start with the current reading in Column B and subtract the previous reading above it also in Column B.

For example, if the proton production reading for UTC 16:40 was 6.7, and the reading for UTC 16:20 is 5.2, the change for Column E is 6.7–5.2, or 1.5 protons.

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Column F: Production Rate

Column F is for the **rate** of production. It answers the question, "How many X-rays or Protons were received by the satellite since the last reading?" To calculate this number, use the number in Column B and divide by the number of minutes since the last reading.

For example, if the X-ray Production reading for 16:00 was 1,515 X-rays, the rate would be 1,515 X-rays//20 min =76 X-rays/min.

Column G: Time to the Next Critical Level

In this column, you must record the time to the next critical level. In order to find this number, take the Critical Value (see Note: to the right) and subtract from it the current reading from Column B. Divide this answer by the rate of change you calculated in Column F. This is the amount of time before the solar storm reaches the next most dangerous level. [Note: *No calculations are necessary for Column G if the trend is not in the direction of criticality—that is, if the result in Column E is a negative number.]*

Column G = Absolute Value of $\frac{\text{Critical value} - \text{Column B}}{\text{Column F}}$

This gives you the time to criticality.

This equation comes to us from the general equation for the slope of a line: $y = mx + b$
If we convert this equation to solve for x, we get this $x = \frac{y - b}{m}$

| If the Current **X-Ray** Category is: | Use This Critical Value |
|---|---|
| R1 | 50 |
| R2 | 100 |
| R3 | 1000 |
| R4 | 2000 |
| R5 | Situation Already Critical |

| If the Current **Proton** Production Category is: | Use This Critical Value |
|---|---|
| S1 | 100 |
| S2 | 1000 |
| S3 | 10,000 |
| S4 | 100,000 |
| S5 | Situation Already Critical |

Note: You must constantly adjust your critical value based on current readings. For instance, if the storm is currently a category R2 or S2, your critical value will be the value for the next most dangerous level— R3 or S3.

Column H: Projection

**X-Ray**: For X-Rays, you are making a **1-hour** projection. Use the rate you calculated in Column F and multiply it by 60 minutes. You will also need to plot this data on a graph.

**Proton**: For Protons, you are making a **24-hour** projection. Use the rate you calculated in Column F and multiply by 1440 minutes. You will also need to plot this data on a graph.

**X-ray:**

You are making a 1-hour projection to determine if a CME or SPE will be forthcoming.

For example, if the hourly X-Ray production for UTC 16:40 is 14 microwatts per minute, then you would expect the rate to jump to 840 microwatts per minute one hour from now (840= 14 * 60).

Note: If your answer is a negative number, use zero (because the sun cannot produce negative amounts of X-Rays).

**Proton:**

You are making a 24-hour projection to determine how large the storm may grow and how long it may last.

For example, if the hourly proton production for UTC 16:45 is 0.12 protons per minute, then you would expect the rate to jump to 173 protons per minute 24 hours from now (173= 0.12* 1440).

Note: If your answer is a negative number, use zero (because the sun cannot produce negative amounts of protons).

Column I and J: Categorize

Take the number you calculated in Column H and determine where that number falls in the ranges given in the table below. Record the corresponding X-ray Category in Column I and Descriptor in Column J. *If the result in Column H was zero, write N/A (not applicable) in these columns.*

| X-Ray Amount (microwatts) | **X-ray Category** | Descriptor |
|---|---|---|
| 0 –50 | R1 | Minor |
| 50-100 | R2 | Moderate |
| 100-1000 | R3 | Strong |
| 1000-2000 | R4 | Severe |
| >2000 | R5 | Extreme |

| Proton Production | **Proton Category** | Descriptor |
|---|---|---|
| 10-99 | S1 | Minor |
| 100-999 | S2 | Moderate |
| 1000-9999 | S3 | Strong |
| 10,000-99,999 | S4 | Severe |
| 100,000+ | S5 | Extreme |

*You may want to refer to the tables given in the Space Weather Reference Guide about X-ray and Solar Radiation Storm impacts on radio and navigation systems to decide if there are any effects to discuss with Mission Control.*

## Instructions for Graphing X-Ray Data

You will be creating two graphs:

- X-Ray Production as a Function of Time

Use the data from Column B for the y-axis values and plot them along the x-axis according to the correct UTC time. The scale for the y-axis values is 0-2,600 microwatts.

- Projected X-Ray Production in 1 hour

Use the data from Column H for the y-axis values and plot them along the x-axis according to the correct UTC time. The scale for the y-axis values is 0-10,000 microwatts.

## Instructions for Graphing Proton Data

You will be creating two graphs:

- Proton Production as a Function of Time

Use the data from Column B for the y-axis values and plot them along the x-axis according to the correct UTC time. The scale for the y-axis values is 0-6,000 protons.

- Projected Proton Production in 24 Hours

Use the data from Column H for the y-axis values and plot them along the x-axis according to the correct UTC time. The scale for the y-axis values is 0-400,000 protons.

**Date:**_____ **STORM Team Data Tracking Table: X-Ray Production**

| Column | A | B* | C | D | E | F | G | H* | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| **Table Headings** | **UTC** | **X-Rays** | **Category** | **Descriptor** | **Change** | **Rate** | **Time to the Next Critical Level**** | **Projected X-Ray Production in 1 Hour** | **Category** | **Descriptor** |
| **Units** | **24 Hour Clock** | **Amount of X-Rays** | **From R1 to R5** | **From Minor to Extreme** | **Amount of X-Rays** | **X-Rays/Min** | **Minutes** | **X-Ray Production** | **From R1 to R5** | **From Minor to Extreme** |
| **Calculations** | **From Data** | **From Data** | **See Reference Guide** | **See Reference Guide** | **B – Previous B** | **B / 20 min** | **G= Critical Value – B / F** | **(F x 60 min)** | **See Reference Guide** | **See Reference Guide** |
| **Example** | 19:20 | 288 | R3 | Strong | 199 | 14 | 51 | 840 | R3 | Strong |
| | 15:00 | | | | n/a | n/a | n/a | n/a | n/a | n/a |
| | 15:20 | | | | | | | | | |
| | 15:40 | | | | | | | | | |
| | 16:00 | | | | | | | | | |
| | 16:20 | | | | | | | | | |
| | 16:40 | | | | | | | | | |
| | 17:00 | | | | | | | | | |
| | 17:20 | | | | | | | | | |
| | 17:40 | | | | | | | | | |
| | 18:00 | | | | | | | | | |
| | 18:20 | | | | | | | | | |
| | 18:40 | | | | | | | | | |
| | 19:00 | | | | | | | | | |
| | 19:20 | | | | | | | | | |
| | 19:40 | | | | | | | | | |

* Graph this column

** You must constantly adjust your critical value based on current readings. For instance, if the storm is currently a category R2 or S2, your critical value will be the value for the next most dangerous level—R3 or S3. Remember, no calculations are necessary for Column G if the trend is not in the direction of criticality—that is, if the result in Column E is a negative number.

**Date:**_____ **STORM Team Data Tracking Table: Proton Production**

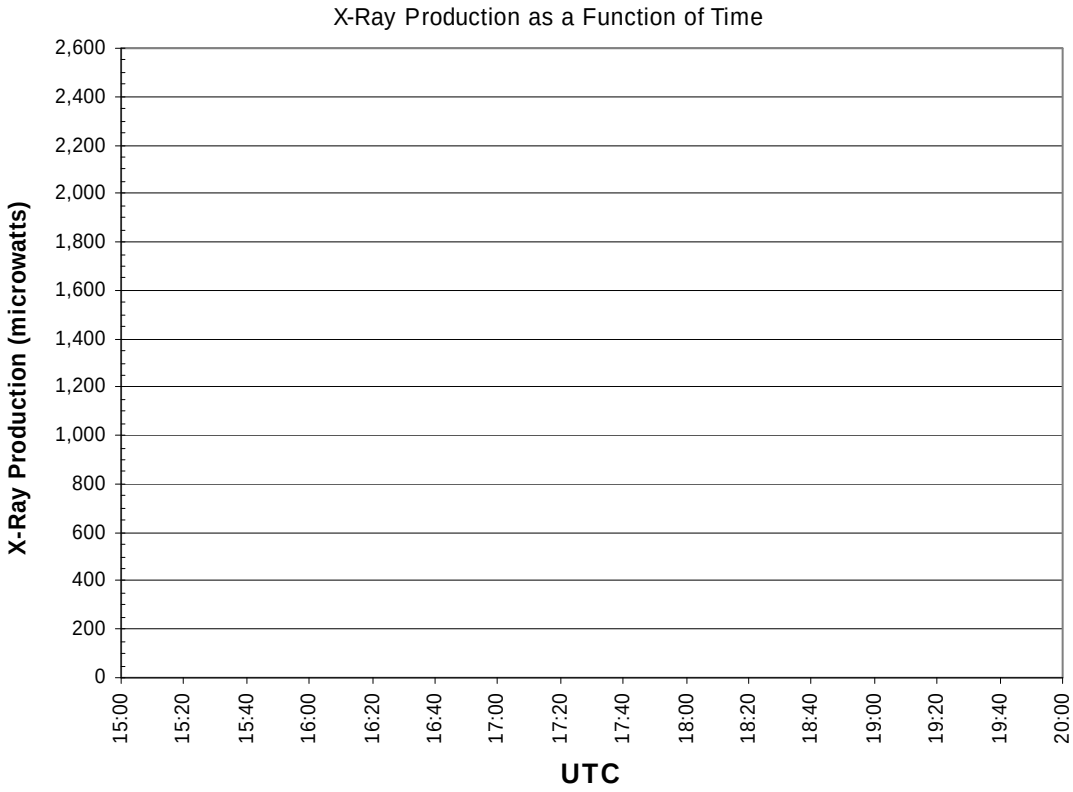
| Column | A | B* | C | D | E | F | G | H* | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| **Table Headings** | **UTC** | **Protons** | **Category** | **Descriptor** | **Change** | **Rate** | **Time to the Next Critical Level**** | **Projected 24 hour Proton Production** | **Category** | **Descriptor** |
| **Units** | **24 Hour Clock** | **Amount of Protons** | **From S1 to S5** | **From Minor to Extreme** | **Amount of Protons** | **Protons/Min** | **Minutes** | **Amount of Protons** | **From S1 to S5** | **From Minor to Extreme** |
| **Calculations** | **From Data** | **From Data** | **See Reference Guide** | **See Reference Guide** | **B – Previous B** | **B / 20 min** | **G= Critical Value – B / F** | **(F x 1440 min)** | **See Reference Guide** | **See Reference Guide** |
| **Example** | 19:20 | 810 | S2 | Moderate | 495 | 41 | 5 | 59,040 | S4 | Severe |
| | 15:00 | | | | n/a | n/a | n/a | n/a | n/a | n/a |
| | 15:20 | | | | | | | | | |
| | 15:40 | | | | | | | | | |
| | 16:00 | | | | | | | | | |
| | 16:20 | | | | | | | | | |
| | 16:40 | | | | | | | | | |
| | 17:00 | | | | | | | | | |
| | 17:20 | | | | | | | | | |
| | 17:40 | | | | | | | | | |
| | 18:00 | | | | | | | | | |
| | 18:20 | | | | | | | | | |
| | 18:40 | | | | | | | | | |
| | 19:00 | | | | | | | | | |
| | 19:20 | | | | | | | | | |
| | 19:40 | | | | | | | | | |

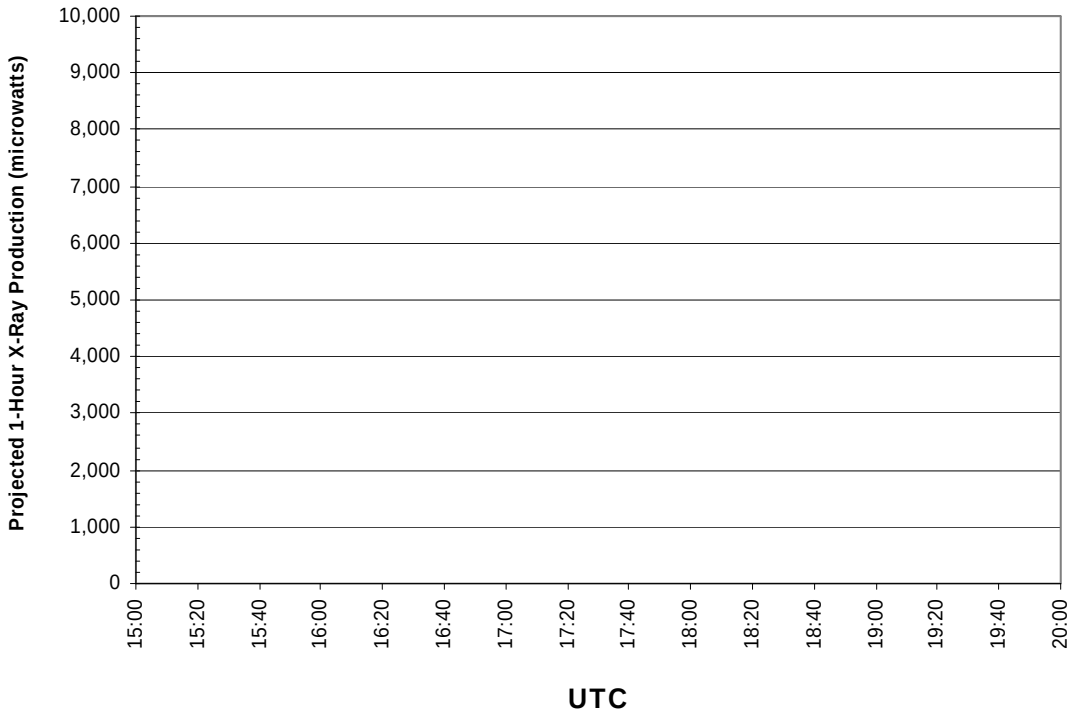
* Graph this column

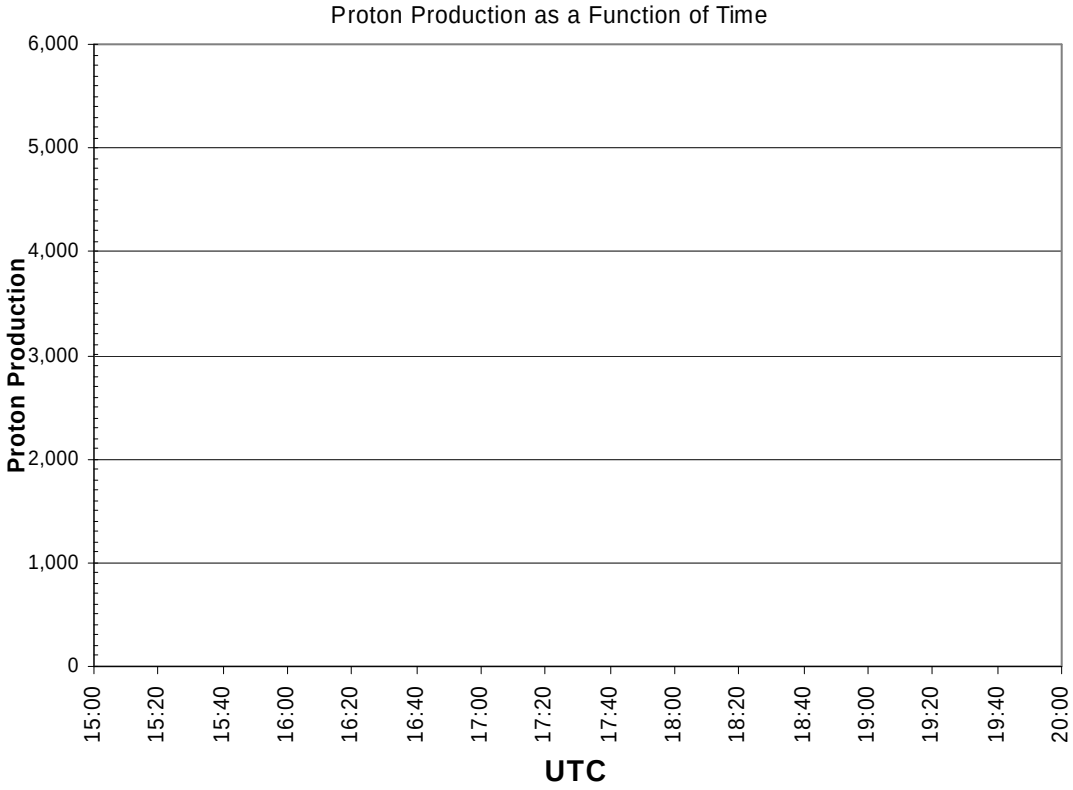
** You must constantly adjust your critical value based on current readings. For instance, if the storm is currently a category R2 or S2, your critical value will be the value for the next most dangerous level—R3 or S3. Remember, no calculations are necessary for Column G if the trend is not in the direction of criticality—that is, if the result in Column E is a negative number.

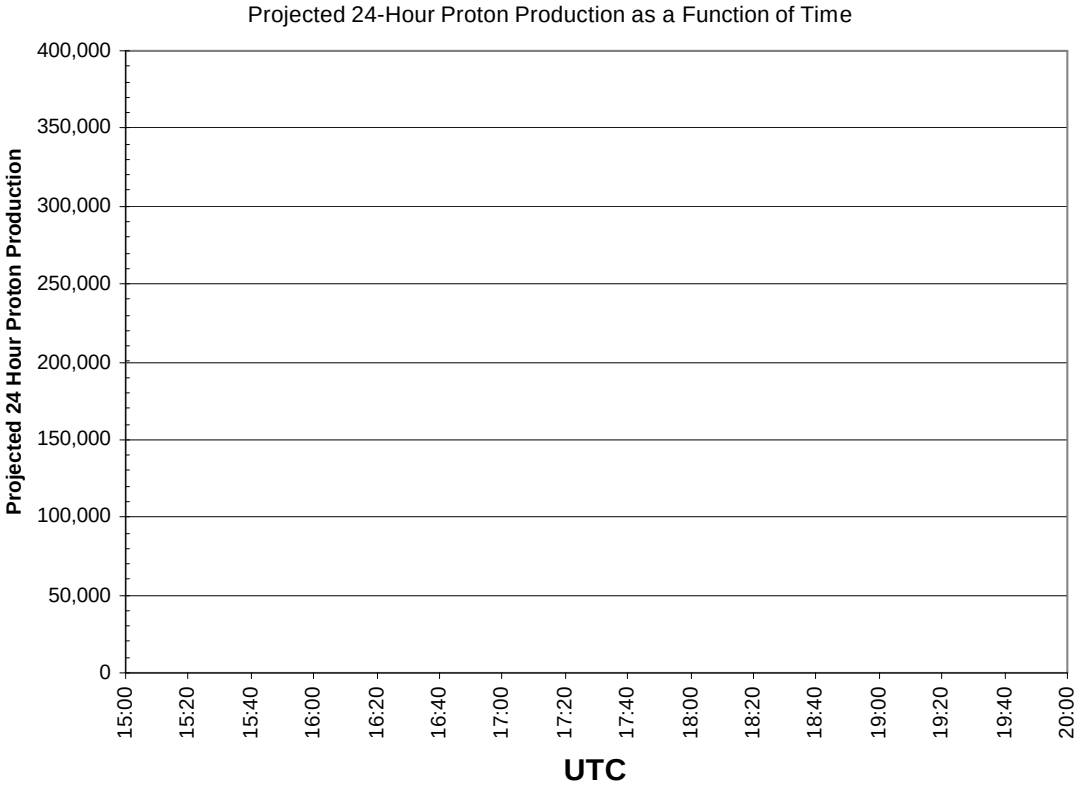
**Practice Data**

| UTC | Amount of Protons | X-Ray (microwatts) |
|---|---|---|
| 15:00 | 45 | 9 |
| 15:20 | 119 | 16 |
| 15:40 | 105 | 46 |
| 16:00 | 350 | 65 |
| 16:20 | 765 | 90 |
| 16:40 | 1,890 | 452 |
| 17:00 | 3,410 | 892 |


X-Ray Production as a Function of Time
X-Ray Production (microwatts)
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40
20:00
UTC


Projected 1-Hour X-Ray Production as a Function of Time
Projected 1-Hour X-Ray Production (microwatts)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40
20:00
UTC


Proton Production as a Function of Time
6,000
5,000
4,000
3,000
2,000
1,000
0
Proton Production
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40
20:00
UTC


Projected 24-Hour Proton Production as a Function of Time
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Projected 24 Hour Proton Production
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40
20:00
UTC

**STORM Team Report Form**

Priority Level (circle one): **1** Urgent – Inform Mission Control Immediately **2** Potential Danger—Monitor Closely **3** Maintaining Normal Levels

**Please fill in ALL blanks in case Mission Control needs the information.**

| | A | B | C | D | G | H | I | J |
|---|---|---|---|---|---|---|---|---|
| **X-Rays** | UTC | X-Rays | Category | Descriptor | Time to Next Critical Level* | Projected 1 Hour X-Ray Production | Category | Descriptor |
| | | | | | | | | |
| | **A** | **B** | **C** | **D** | **G** | **H** | **I** | **J** |
| **Protons** | UTC | Protons | Category | Descriptor | Time to Next Critical Level* | Projected 24 hour Proton Production | Category | Descriptor |
| | | | | | | | | |

*Communication Team: Please do NOT report the shaded areas to Mission Control.*

Recommendations:

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**STORM Team Report Form**

Priority Level (circle one): **1** Urgent – Inform Mission Control Immediately **2** Potential Danger—Monitor Closely **3** Maintaining Normal Levels

**Please fill in ALL blanks in case Mission Control needs the information.**

| | A | B | C | D | G | H | I | J |
|---|---|---|---|---|---|---|---|---|
| **X-Rays** | UTC | X-Rays | Category | Descriptor | Time to Next Critical Level* | Projected 1 Hour X-Ray Production | Category | Descriptor |
| | | | | | | | | |
| | **A** | **B** | **C** | **D** | **G** | **H** | **I** | **J** |
| **Protons** | UTC | Protons | Category | Descriptor | Time to Next Critical Level* | Projected 24 hour Proton Production | Category | Descriptor |
| | | | | | | | | |

*Communication Team: Please do NOT report the shaded areas to Mission Control.*

Recommendations:

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