

PACER 2.0

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Agenda

1. What is PACER and where did it come from?
2. What is the status of PACER?
3. How is PACER operated to perform analysis?
4. How is PACER being used to support the Artemis program?
5. What are the near-term plans for further PACER updates?

What is PACER and where did it come from?

- Probabilities of Atmospheric Conditions and Environmental Risk (PACER) is a MSFC Natural Environments analysis tool used for estimating mission phase (launch, landing) availabilities with respect to weather and near-surface environments.
- Evolved during the Constellation program from the existing Atmospheric Parametric Risk Assessment (APRA) analysis tool.
 - Constellation analysis required capabilities not available in APRA.
 - A Graphical User Interface (GUI) was included to simplify operation.
 - A methodology was developed to speed implementation of new parameters and locations.
 - PACER uses long time-series of coincident observed data to compute probabilities of encountering various sets of user-specified environmental conditions.
- Results (GO/NOGO) probabilities are given by month and hour of the day.

What is the status of PACER?

- PACER version 2.0 has recently been developed.
- An accompanying user's and programmer's guide has been produced.
- Updated GUI to focus specifically on Artemis analysis requirements.
- Options to enter threshold values in either standard or metric units. All computations are done in metric units.
- Previous production version, PACER 1.0, Build 6, is still available to support other projects and analyses.

What is the status of PACER?

- PACER 2.0 analyzes the following constraint parameters:
 - Low temperature
 - High temperature
 - Nearest lightning distance
 - Mean winds
 - Peak winds
 - Precipitation
 - Sea states
- Wind, temperature data from Tower 313. Precipitation data from KSC rain gauges. Lightning distances from custom National Lightning Detection Network (NLDN) archive. Sea states will use European Center for Medium-Range Weather Forecasts Reanalysis version 5 (ERA-5) data.

How is PACER operated to perform analysis?

1. Launch program.
2. Manipulate GUI controls to establish scenario constraints for parameters of choice.
3. Select executive options.
4. Run.

How is PACER operated to perform analysis?

The screenshot shows the initial GUI state of the PACER application. The window is titled "IDL" and contains several control panels for various environmental parameters.

- Executive Controls:** Contains "Run" and "Exit" buttons, and checkboxes for "Save vector outputs" and "Include failure modes".
- Low Temperature Controls:** Radio buttons for "No constraint" (selected), "Set thresholds", and "Use table".
- High Temperature Controls:** Radio buttons for "No constraint" (selected) and "Set thresholds".
- Lightning Distance Controls:** Radio buttons for "No constraint" (selected) and "Set threshold".
- Sea State Controls:** Radio buttons for "No constraint" (selected), "Az=90, nominal", and "Az=90, off-nominal".
- Mean Wind Controls:** Radio buttons for "No constraint" (selected), "Set thresholds", "Use AR-02 placard", and "Use 24 kt uni placard". A large empty box is present.
- Peak Wind Controls:** Radio buttons for "No constraint" (selected), "Set thresholds", "Use AR-02 placard", and "Use 24 kt uni placard". A large empty box is present.
- Precipitation Controls:** Radio buttons for "No constraint" (selected) and "Select Gauges". An aerial map shows locations labeled "LC 39B", "VAB", "RG 08", "RG 09", "RG 12", "RG 14", and "RG 15".

Initial GUI state upon launch

How is PACER operated to perform analysis?

Low Temperature Controls

☒ No constraint

☐ Set thresholds

☐ Use table

Initial status

Low Temperature Controls

☐ No constraint

☒ Set thresholds

☐ Use table

☐ 54 ft height 0.0 C, or 32.0 F

☒ 204 ft height 0.0 C, or 32.0 F

"Set thresholds" selected

Low Temperature Controls

☐ No constraint

☐ Set thresholds

☒ Use table

"Use table" selected

SLS Low temperature constraint table (shown here for reference, not displayed in GUI)

Mean wind speed at 54 ft (knots)	Relative humidity at 54 ft height		
	< 65%	65 to 80%	> 80%
< 2.1	49	48	46
2.1 to 3.0	43	43	43
3.1 to 4.0	43	43	43
4.1 to 7.0	40	40	40
7.1 to 14.0	39	39	39
> 14.0	38	38	38

How is PACER operated to perform analysis?

High Temperature Controls

☒ No constraint

☐ Set thresholds

Initial status

High Temperature Controls

☐ No constraint

☒ Set thresholds

☒ 54 ft height C, or F

☐ 204 ft height C, or F

"Set thresholds" selected

How is PACER operated to perform analysis?

Lightning Distance Controls

☒ No constraint

☐ Set threshold

Initial status

Lightning Distance Controls

☐ No constraint

☒ Set threshold

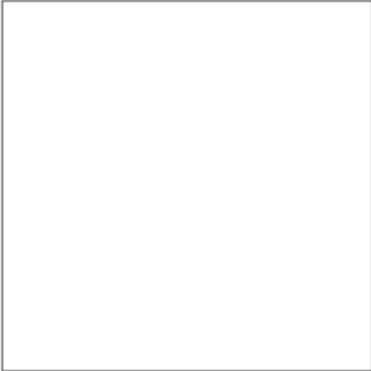
km, or nmi

“Set threshold” selected

How is PACER operated to perform analysis?

Mean Wind Controls

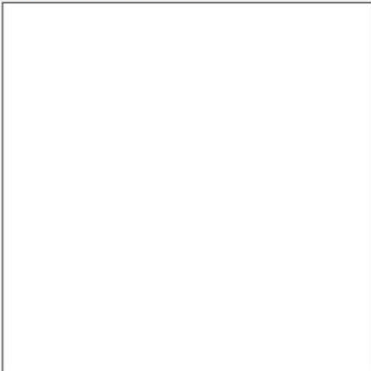
☒ No constraint
☐ Set thresholds
☐ Use AR-02 placard
☐ Use 24 kt uni placard



Initial status

Mean Wind Controls

☐ No constraint
☒ Set thresholds
☐ Use AR-02 placard
☐ Use 24 kt uni placard



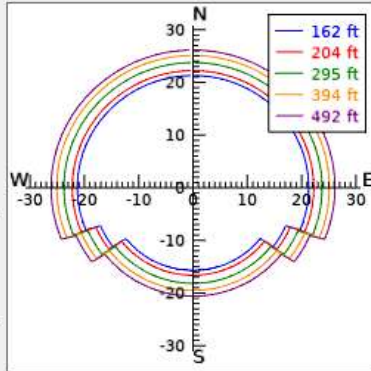
☐ 54 ft height 0.0 m/s, or 0.0 kts
☐ 162 ft height 0.0 m/s, or 0.0 kts
☐ 204 ft height 0.0 m/s, or 0.0 kts
☐ 295 ft height 0.0 m/s, or 0.0 kts
☐ 394 ft height 0.0 m/s, or 0.0 kts
☐ 492 ft height 0.0 m/s, or 0.0 kts

“Set thresholds” selected

Mean Wind Controls

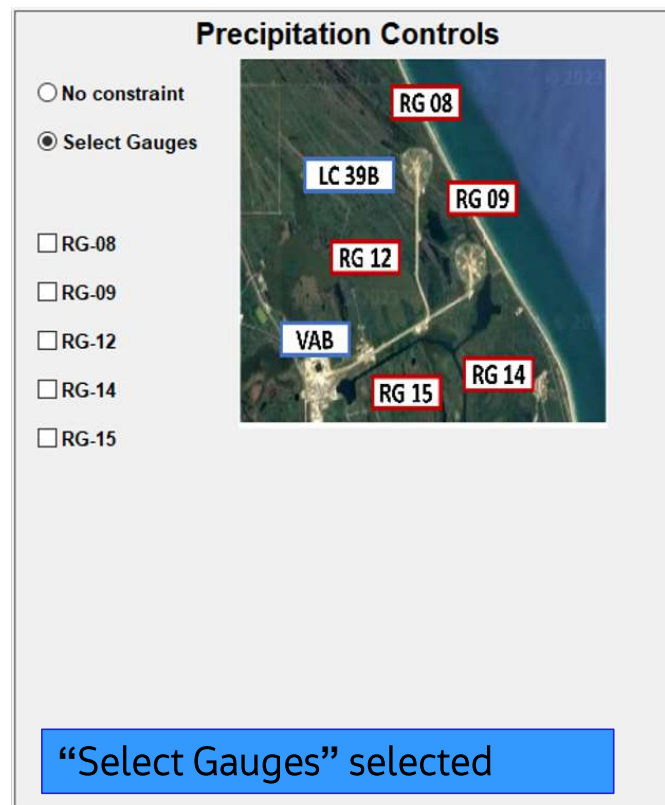
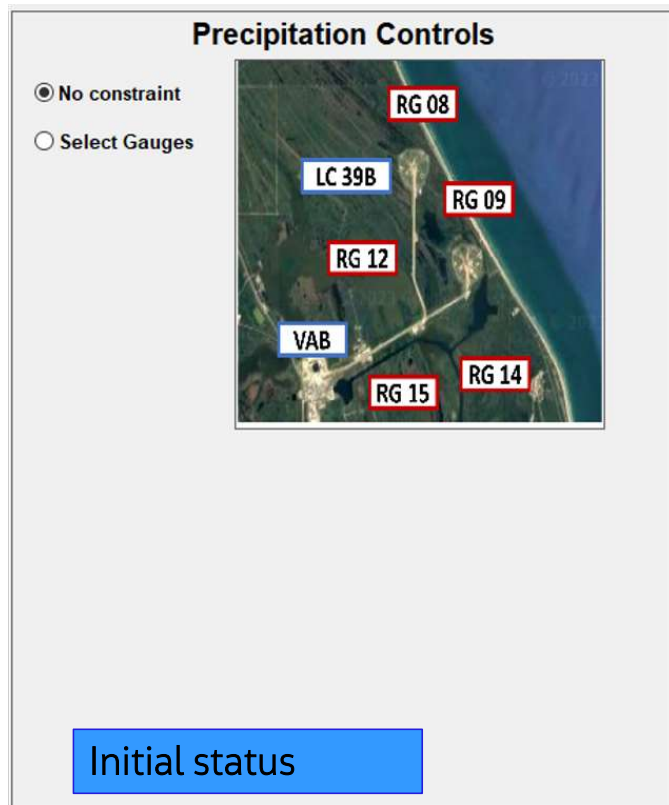
☐ No constraint
☐ Set thresholds
☒ Use AR-02 placard
☐ Use 24 kt uni placard

Display unit
☒ m/s ☐ kts



“Use AR-02 placard” selected

How is PACER operated to perform analysis?



How is PACER operated to perform analysis?

Executive Controls

Run

Exit

☐ Save vector outputs

☐ Include failure modes

Create output file showing pass/fail status at each reporting interval.

Analyze each input parameter separately, in addition to the full set of defined constraints.

How is PACER operated to perform analysis?

Coincident input data for all parameters			Count valid intervals (N_V)	Count constraint failures (N_F)
	Parameter 1	Parameter 2		
Common Period of Record	Hour 1	6.4	Valid	Pass
	Hour 2	7.1	Valid	Fail
	Hour 3	NaN	Invalid	
	⋮	⋮	⋮	⋮
	Hour N-1	7.9	Valid	Pass
	Hour N	5.4	Valid	Pass

Example:

- Parameter 1 threshold:
Value > 8.0 = fail
- Parameter 2 threshold:
Value > 21.0 = fail

Compute Probabilities

$$P(\text{NOGO}) = 100\% * N_F / N_V$$

$$P(\text{GO}) = 100\% - P(\text{NOGO})$$

How is PACER operated to perform analysis?

Standard output file

Header information: constraint list,
date/time of execution, data period
of record, etc.

Table 1: Count of valid observations
Table 2: Count of constraint set fails
Table 3: Probability of constraint
failure (% NOGO)

For each constraint... (assuming
failure mode option is selected)
Table 1: Count of constraint fails
Table 2: Probability of constraint
failure

Hour (UTC)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All months
0													
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
All hours													

Specific hour/all months

Specific hour/month combinations

All hours/specific month

All hours/all months (net annual)

How is PACER being used to support the Artemis program?

- PACER outputs are used to support Discrete Event Simulation model (KSC/Exploration Ground Systems-led effort) to address Moon-to-Mars program launch probability Technical Performance Measures 7B and 7C.
- New outputs are generated quasi-quarterly, assuming dataset updates are available, new capabilities have been added, or program constraints have been updated.
- Results are transmitted via official memo to personnel at KSC.
- Results were provided throughout the lead-up to the Artemis I launch and were used to compute program-wide launch probabilities.
- Results are being developed and provided for Artemis II mission planning.
- Artemis II results will eventually include abort sea states due to crewed mission.
- PACER will continue to support the Artemis program through Artemis III and beyond.

What are the near-term plans for further PACER updates?

- PACER 2.0 is implementing a major upgrade in the way sea states are analyzed, compared to PACER 1.0.
- Analysis will consider cumulative probabilities of aborts throughout the ascent trajectory, greatly reducing excess conservatism.
- Additional abort zone parameters are being included to better coincide with anticipated day of launch monitoring practices.
- Due to the new methodology, datasets for specific launch scenarios and parameter constraints need to be produced prior to implementation into PACER. These are currently being developed.

Summary

- PACER 2.0 is the latest in a long line of MSFC Natural Environments analysis tools for computing launch availability with respect to weather and near-surface environmental conditions.
- The PACER GUI provides easy customization of analysis scenarios.
- PACER has and will continue to provide support for Artemis program mission planning.
- New sea state analysis methodology is being developed that will include more realistic (based on expected day of launch monitoring) constraint checks while also reducing excess conservatism.
- Questions?