Hazard detection, landing ellipse and landing-site selection

Guiding question

Concrete → vocabulary → diagram → calculation → limits → mission.

Course map

The real phenomenon → Vocabulary and problem boundary → Course-specific system view → Mathematical relationship and reading the symbols → Worked calculations and interpretation

1 — The real phenomenon

Navigation, atmosphere, propulsion performance and sensors create dispersion. A probability region or ellipse is therefore more realistic than a perfect point. Hazard detection then seeks to avoid slopes, boulders, craters or areas incompatible with stability and surface operations. For human missions, proximity to infrastructure must be balanced against plume effects and facility safety.

The guiding question is: Why does aiming at a point never mean guaranteeing touchdown exactly there? Reasoning starts with the physical or operational function before introducing the mathematical relationship. The goal is not to accumulate terminology, but to know which quantity changes, why it changes and what becomes hazardous when it leaves its domain. For “Hazard detection, landing ellipse and landing-site selection”, the first task here is therefore to identify the mechanism specific to this subject before searching for an equation or reference value.

2 — Vocabulary and problem boundary

In “Hazard detection, landing ellipse and landing-site selection”, distinguish the phenomenon, available measurement, any command, the margin and the success criterion. The calculation boundary states what is included and excluded; without that boundary, a percentage, mass or time may be mathematically correct but wrong as an engineering conclusion. For “Hazard detection, landing ellipse and landing-site selection”, the chosen boundary also states what would otherwise be double-counted or omitted from a mission budget.

slope, rocks, local relief, position uncertainty, reachable ellipse and divert reserve

a hazard missing from the map, false safe terrain, a solution arriving too late or insufficient divert reserve

orbital maps, ground-truth data sets, false-positive/false-negative scenarios and safe-target selector tests

Equation - evidence - decision

$A_{ellipse} = \pi \times a \times b$; $pente = \Delta h/L$

Failure to test: The reference failure is not a vague “broken component.” For “Hazard detection, landing ellipse and landing-site selection”, test in particular a hazard missing from the map, false safe terrain, a solution arriving too late or insufficient divert reserve. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

Hazard detection, landing ellipse and landing-site selection

3 — Course-specific system view

This lesson does not reuse one generic picture for every subject. The system view follows cause → measured quantity → decision or physical response → limit for “Hazard detection, landing ellipse and landing-site selection”. The English text remains fully equivalent while large translated illustrations are intentionally deferred until their dedicated artwork is supplied. For “Hazard detection, landing ellipse and landing-site selection”, the system view must expose inputs, outputs, measured quantity and the consequence of drift without relying on a generic module diagram.

4 — Mathematical relationship and reading the symbols

Read aloud : ellipse area equals pi times semi-major axis a times semi-minor axis b; slope is elevation change delta h divided by horizontal distance L.

Before substituting numbers, write the unit of every term, state whether the relationship is a physical law, approximation or project indicator, and check dimensional consistency. This is especially important here because “Hazard detection, landing ellipse and landing-site selection” combines quantities that do not all have the same evidence status. For “Hazard detection, landing ellipse and landing-site selection”, this relationship is chosen because of the phenomenon under study; a different dominant quantity would require a different equation or model.

5 — Worked calculations and interpretation

a=4 km, b=3 km → $A \approx \pi \times 4 \times 3 = 37.70\ km^2$

3/50 = 0.06 = 6%; angle ≈ atan(0.06)=3.43°

1. 1. 8 km × 6 km ellipse a=4 km, b=3 km → $A \approx \pi \times 4 \times 3 = 37.70\ km^2$ Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Hazard detection, landing ellipse and landing-site selection”.
2. 2. Slope 3/50 = 0.06 = 6%; angle ≈ atan(0.06)=3.43° Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Hazard detection, landing ellipse and landing-site selection”.
3. 3. Teaching accelerated divert $0.5 \times 1.5 \times 20^2 = 300$ m Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Hazard detection, landing ellipse and landing-site selection”.

6 — What the formula does not contain

Operational table

Phenomena / sections:	3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation
Relationship to revisit:	A_ellipse = π × a × b ; pente = Δh/L
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation. State one measured quantity, one margin and one possible decision.

Hazard detection, landing ellipse and landing-site selection

The relationship “A_ellipse = π × a × b ; pente = Δh/L” does not by itself contain all of “Hazard detection, landing ellipse and landing-site selection”. It does not automatically tell us whether a sensor is valid, a structure is aging, a resource is accessible, a command arrives in time or a secondary failure removes margin. The example a=4 km, b=3 km → A≈π×4×3 = 37.70 km² therefore remains a local calculation rather than a complete architecture.

To make the model useful, explicitly add the quantities that dominate this subject: slope, rocks, local relief, position uncertainty, reachable ellipse and divert reserve. We can then ask which variation truly changes the result, which is negligible and which forces an architectural change. For “Hazard detection, landing ellipse and landing-site selection”, this model limitation states exactly what a correct calculation still cannot establish about the real system.

7 — Instrumentation, observability and data quality

For “Hazard detection, landing ellipse and landing-site selection”, observability relies on slope, rocks, local relief, position uncertainty, reachable ellipse and divert reserve. Each datum has a unit, acquisition rate, uncertainty, timestamp and validity domain. A value arriving without context can be more dangerous than no measurement because it creates unjustified confidence.

Consistency is checked with at least one independent piece of information when the function is critical. A trend, physical balance or second measurement principle helps distinguish a real system change from a drifting sensor. For “Hazard detection, landing ellipse and landing-site selection”, the selected instrumentation must distinguish a real physical change from sensor drift or a bad state estimate.

8 — Phenomenon-specific failures and recovery

The reference failure is not a vague “broken component.” For “Hazard detection, landing ellipse and landing-site selection”, test in particular a hazard missing from the map, false safe terrain, a solution arriving too late or insufficient divert reserve. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

The degraded mode must be defined before failure: minimum function, allowable duration, consumed stock, crew action, abort condition and return-to-nominal criterion. That sequence is topic-specific and cannot be replaced by one universal paragraph about redundancy. For “Hazard detection, landing ellipse and landing-site selection”, the degraded mode is defined around the minimum function specific to this subject, with an abort threshold and a return-to-nominal condition.

Operational table

Phenomena / sections:	7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery
Relationship to revisit:	A_ellipse = π × a × b ; pente = Δh/L
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery. State one measured quantity, one margin and one possible decision.

Hazard detection, landing ellipse and landing-site selection

9 — NASA / reference case

Mars 2020 safe-target selection combines position knowledge with a hazard map. A statistical ellipse is not merely “where we might land”: it must be confronted with reachable safe zones, divert reserve and the last time a decision can still be executed.

The case is used only within what it actually demonstrates. Flight measurement, human-system standard, component test and architecture study are different kinds of evidence; the text therefore states what is observed, calculated, simulated or still prospective. For “Hazard detection, landing ellipse and landing-site selection”, the cited NASA case is used as targeted evidence for this phenomenon and is never turned into one universal Mars architecture.

10 — Architecture trade

A good solution for “Hazard detection, landing ellipse and landing-site selection” does not maximize one metric. Compare nominal performance, mass, energy, simplicity, maintenance, crew time, common dependencies and recoverability. An option that improves $3/50 = 0.06 = 6\%$; angle $\approx \mathrm{atan}(0.06)=3.43°$ can still be rejected if it makes failure detection or repair much harder.

The trade is recorded together with its assumptions. If environment data, mass or mission cadence changes, we know which conclusions must be recomputed instead of silently preserving an obsolete choice. For “Hazard detection, landing ellipse and landing-site selection”, the trade is evaluated against the interfaces actually touched by this subject rather than a generic list of desirable qualities.

11 — Demonstration, testing and success criteria

The evidence strategy for “Hazard detection, landing ellipse and landing-site selection” combines orbital maps, ground-truth data sets, false-positive/false-negative scenarios and safe-target selector tests. Every test records exact hardware, software, configuration, environment, tolerances and success criterion. A successful demonstration outside the mission domain does not replace qualification inside it.

Evidence grows by levels: analytical relationship, simulation, component, subsystem, integrated system, duration and failure. This hierarchy prevents one spectacular test from being presented as validation of the whole mission. For “Hazard detection, landing ellipse and landing-site selection”, demonstration must reproduce the constraints that make this phenomenon difficult; a spectacular test outside the mission domain is insufficient.

Operational table

Phenomena / sections:	9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria
Relationship to revisit:	$A\_ellipse = \pi \times a \times b$; $pente = \Delta h/L$
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria. State one measured quantity, one margin and one possible decision.

Hazard detection, landing ellipse and landing-site selection

12 — Decision exercise

Situation: revisit “Hazard detection, landing ellipse and landing-site selection” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable.

Situation: revisit “Hazard detection, landing ellipse and landing-site selection” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable. Expected answer: recompute the relationship, identify remaining margin, check whether observability is still adequate, and decide whether degraded operation remains acceptable. Multiplying by 1.2 is not enough if the variation also changes interfaces or limits.

13 — What to retain without over-generalizing

14 — Topic-specific primary sources

These references directly document the phenomenon, technology or human constraint addressed in this lesson. They do not by themselves define an official Mars architecture. For “Hazard detection, landing ellipse and landing-site selection”, the bibliography is deliberately targeted to this page so that readers can trace each claim back to the relevant primary document.

Topic-specific primary sources

NASA NTRS — Mars 2020 EDL GNC Safe Target Selection - https://ntrs.nasa.gov/citations/20230005646

NASA NTRS — Precision Landing & Hazard Avoidance - https://ntrs.nasa.gov/citations/20170001719

NASA NTRS — The Lander Vision System for Mars 2020 EDL - https://ntrs.nasa.gov/citations/20190025658

Operational table

Phenomena / sections:	12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources
Relationship to revisit:	$A_{ellipse} = \pi \times a \times b$; pente = $\Delta h/L$
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources. State one measured quantity, one margin and one possible decision.