Flight Management Computer System
Vertical Navigation
aka
VNAV

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Very Short History

- **Lateral Navigation (LNAV) and Vertical Navigation (VNAV) were first implemented on 757 and 767 in 1982.**
- **Original intent of the features was for enroute navigation. No early vision into future operations such as RNP / RNAV (terminal area) / GPS / 4 D paths.**
- **Performance of both LNAV and VNAV has been enhanced and continue to be improved as performance-based operations mature.**

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Feature Description

LNAV

- **LNAV provides a precise lateral path defined by waypoints and legs (Flight Plan Route).**
- **LNAV computes guidance commands for the Autopilot or Flight Director to follow the path.**

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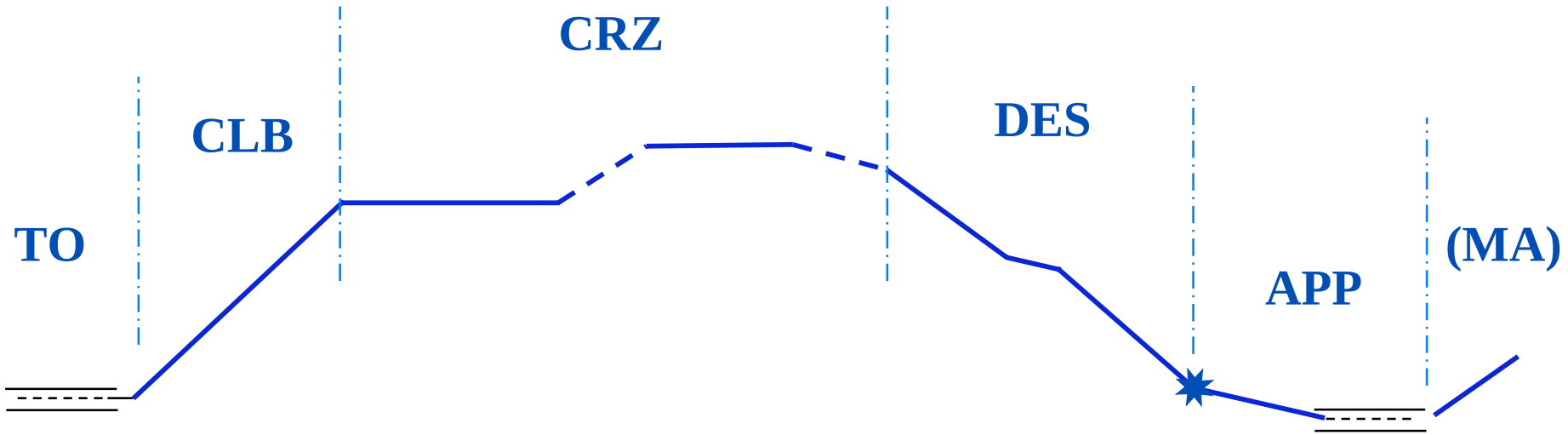
Feature Description

VNAV

- **VNAV is the vertical navigation flight profile which is the predicted flight trajectory of the airplane in the vertical plane as a function of distance along the horizontal flight path defined by the LNAV flight plan.**
- **The flight profile reflects all speed and altitude restrictions specified in the guidance flight plan while honoring airplane operating limits.**
- **VNAV computes guidance commands for the Autopilot or Flight Director and Autothrottle to follow the vertical profile.**

VNAV

Flight Phases



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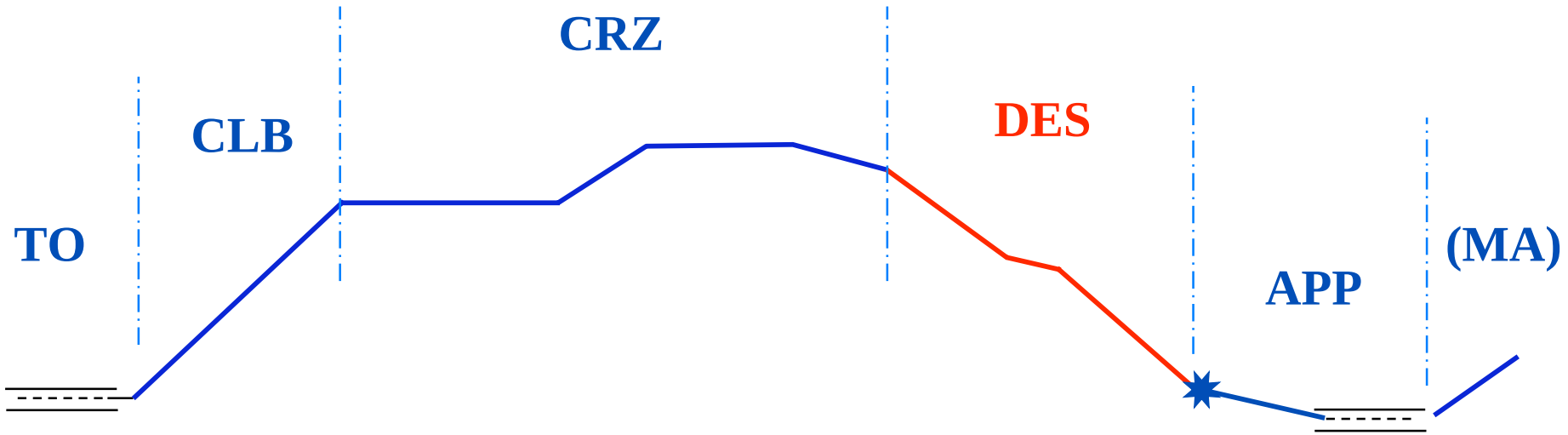
CDA - Descent Phase



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Ground Rules

- **The VNAV Path is constructed upstream beginning at the lowest waypoint constraint (generally the runway or missed approach point) up to the final cruise altitude.**
- **The path is constructed by connecting one or more altitude constrained waypoints and the top-of-descent point.**
- **Depending upon the number of constrained waypoints in the descent, two path types exist:**
  - **Performance Path**
  - **Geometric Path**

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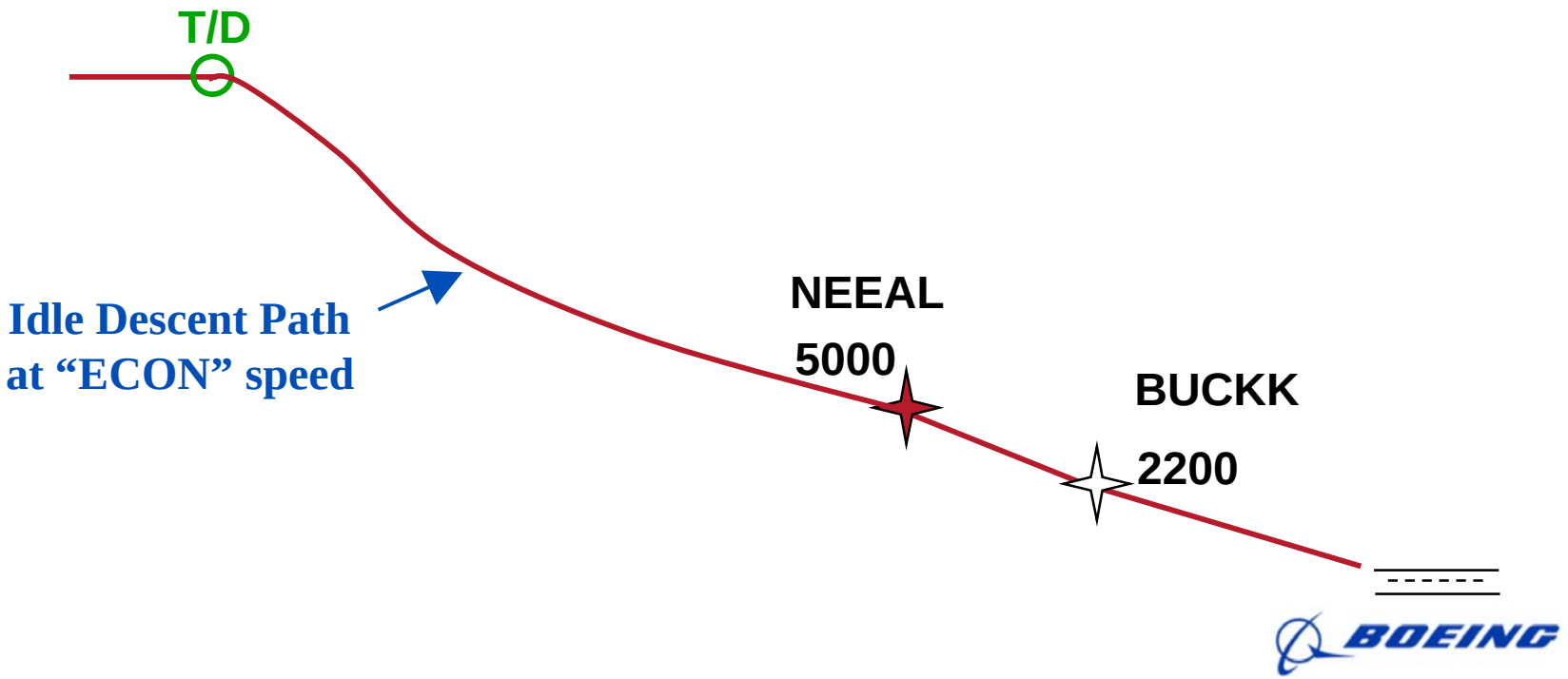
More Ground Rules

- **Performance Path - computed path descent at idle power from top-of-descent to the first constrained waypoint**



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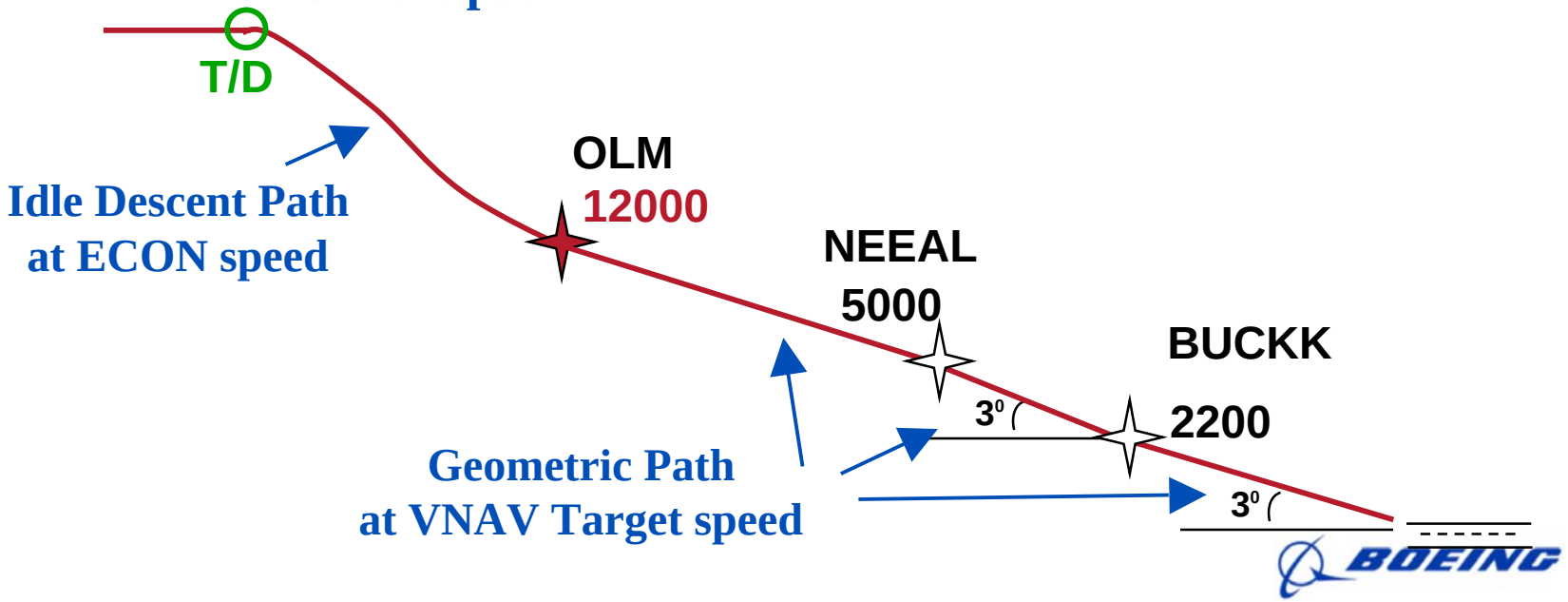
More Ground Rules

- **Geometric path - computed "point-to-point" path descent between two constrained waypoints or when tracking a prescribed vertical angle**
  - **The geometric path is a shallower descent and typically a non-idle path**



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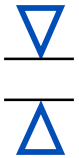
Path Construction

- **The flight profile reflects all speed and altitude restrictions specified in the guidance flight plan while honoring airplane operating limits.**
- **Altitude Constrained Waypoints**
  - **"AT" altitude** 
  - **"AT or Above"** 
  - **"AT or Below"** 
  - **"Window"** 

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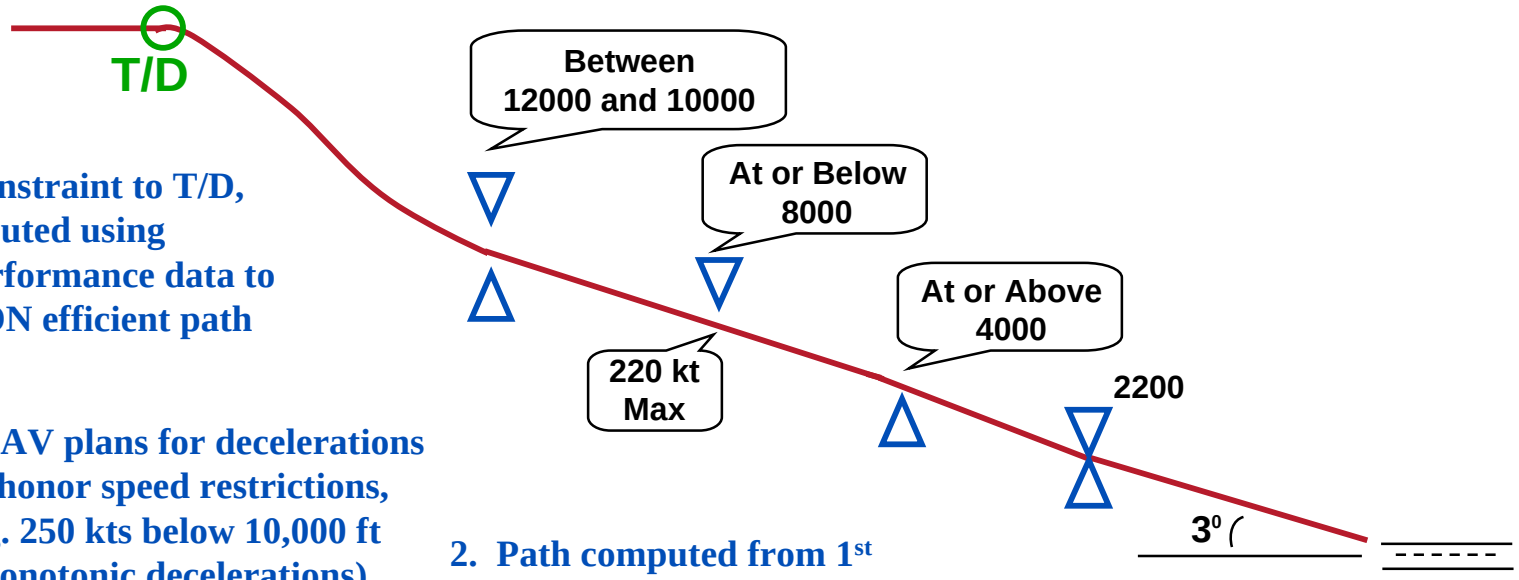
Path Construction



4. From last constraint to T/D, path is computed using available performance data to achieve ECON efficient path

3. VNAV plans for decelerations to honor speed restrictions, e.g. 250 kts below 10,000 ft (monotonic decelerations)

2. Path computed from 1st constraint to next constraint that "gets in the way" and then the next, and so on …. Energy management plays a roll on geometric legs

1. VNAV begins at runway and follows vertical angle

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Influences on Path Construction

- **Computation of the path is influenced by several factors**
  - **Airplane type and performance**
  - **Gross weight**
  - **Anti-icing (higher idle thrust)**
  - **Weather**
    - **Winds**
    - **Temperature**

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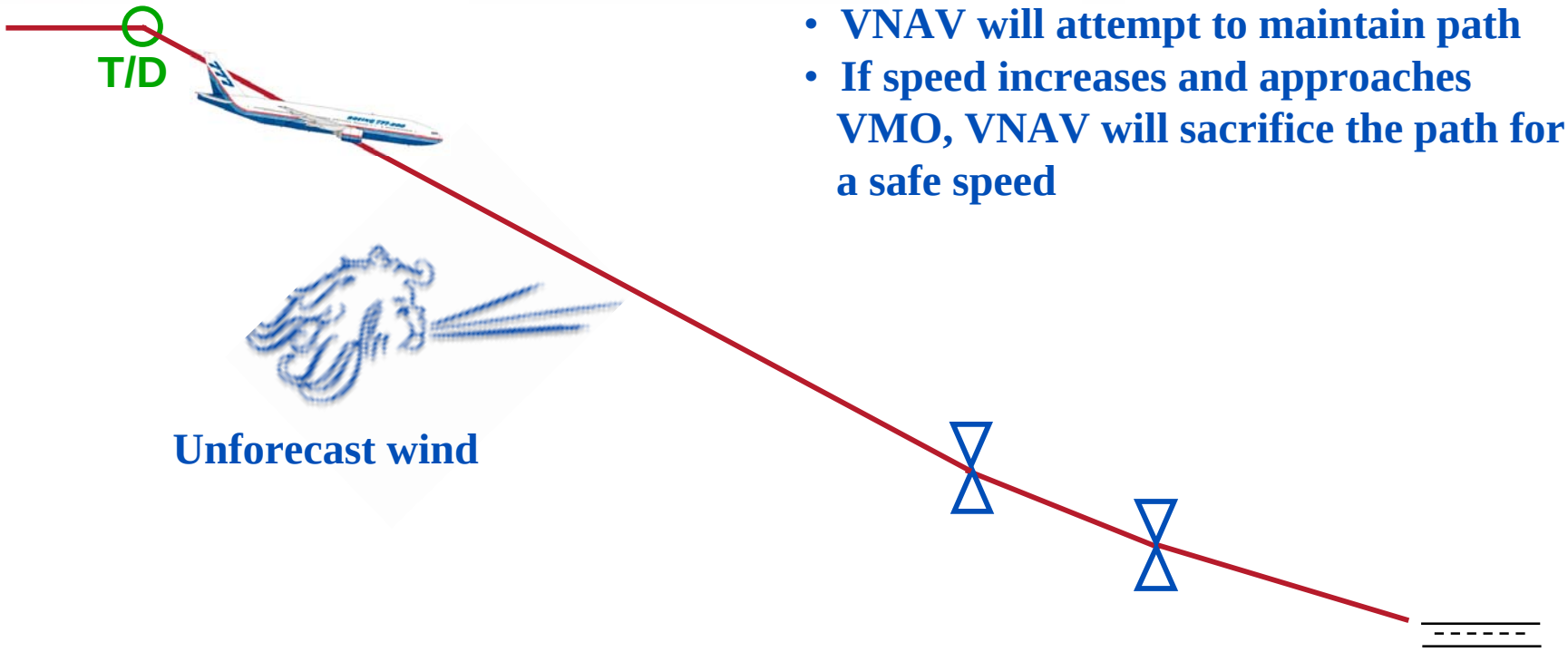
Influences on Path Construction



- VNAV will attempt to maintain path
- If speed increases and approaches VMO, VNAV will sacrifice the path for a safe speed

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Operation Summary

- **The path is determined via speed and altitude constraints along the LNAV path.**
- **The path can be either "performance" or "geometric."**
  - **The geometric path is typically a shallower descent and a non-idle path. VNAV will manage energy to comply with speed restrictions.**
- **Numerous factors influence path computation.**
- **Given good data (wind, temp, e.g.), VNAV will provide a consistently operational path.**

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CDA

Operational Considerations

- **Not all airplanes are equipped with VNAV and those that are equipped may vary in operation.**
- **Different airframes perform differently.**
- **Given the variability in equipage, disciplined procedure design may be the preferred CDA methodology.**
- **Procedures that incorporate a well-defined path may have the best opportunity for success.**
  - **I.e., procedures that define altitude targets and speeds and incorporate a flight path angle that accommodates the users will provide consistent paths.**
- **However, less restrictive paths may accommodate more users, save fuel, but increase variability and spacing down the chute.**

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Everything comes together at the pointy end