An Assessment of Launch Failures from 1989 - Present

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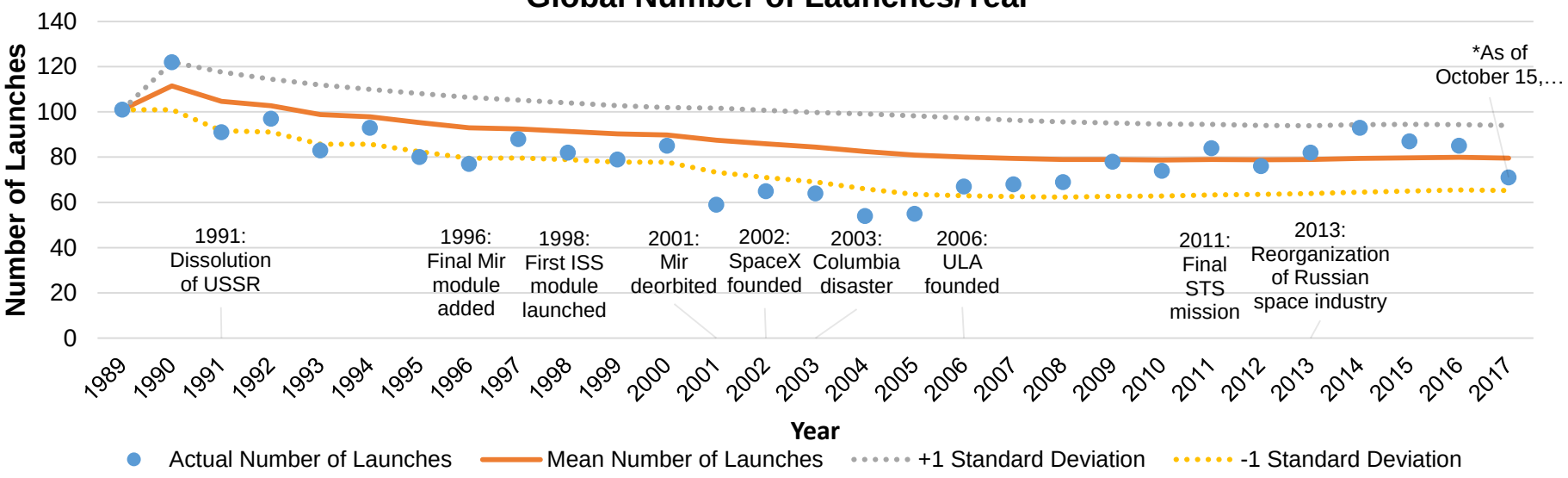
Agenda

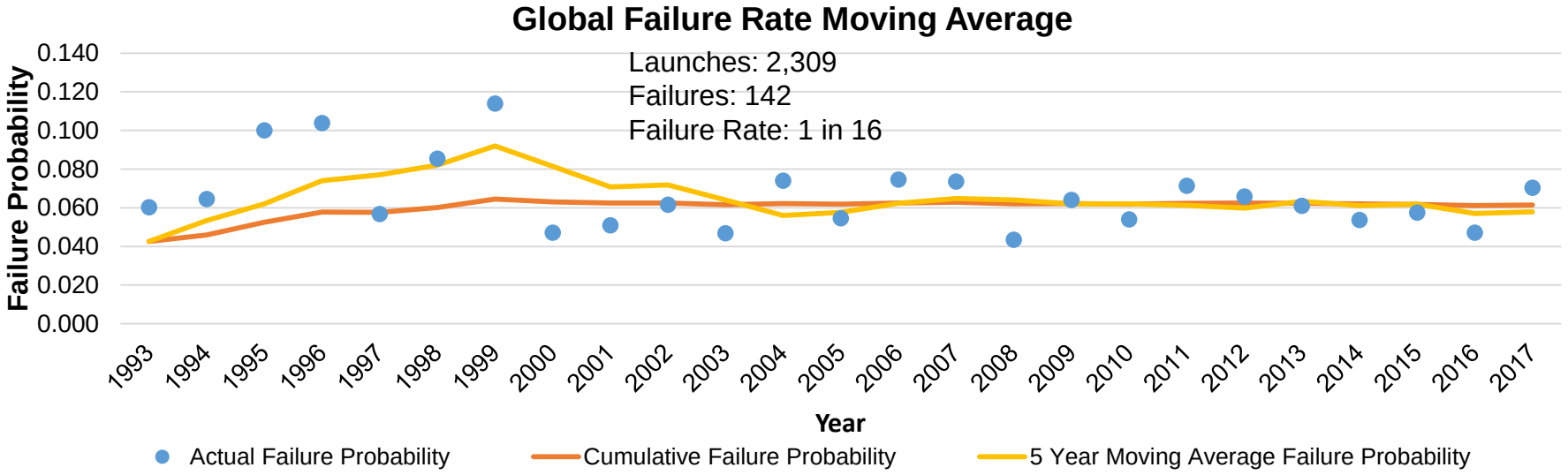
- **Review international binary (success and failure) launch data from the past three decades**
  - Launch data for 2017 considered for launches up to October 15, 2017
- **Identify relevant trends**
- **Forecast future launch failure probability**

Assumptions

- **Partial launch failures involving spacecraft loss of mission or shortened operating life (e.g. spacecraft placed in incorrect orbit by launch vehicle) are considered launch failures**
- **The launch failure database and failure proximate causes from international launch attempts was compiled from publicly-available sources; international mishap investigations may reveal incomplete system failure information**
- **The scope of this presentation is limited to binary (success and failure) launch data and does not account for launch vehicle reliability growth or evolution of the "state of the art"**
- **In determining failure rate for years in which no failures were recorded, the Rule of Three was honored for a conservative estimate**
  - If an event does not occur in a population of size *n*, the interval from 0 to 3/*n* is a 95% confidence interval for the rate of occurrences in *n* for *n*>30

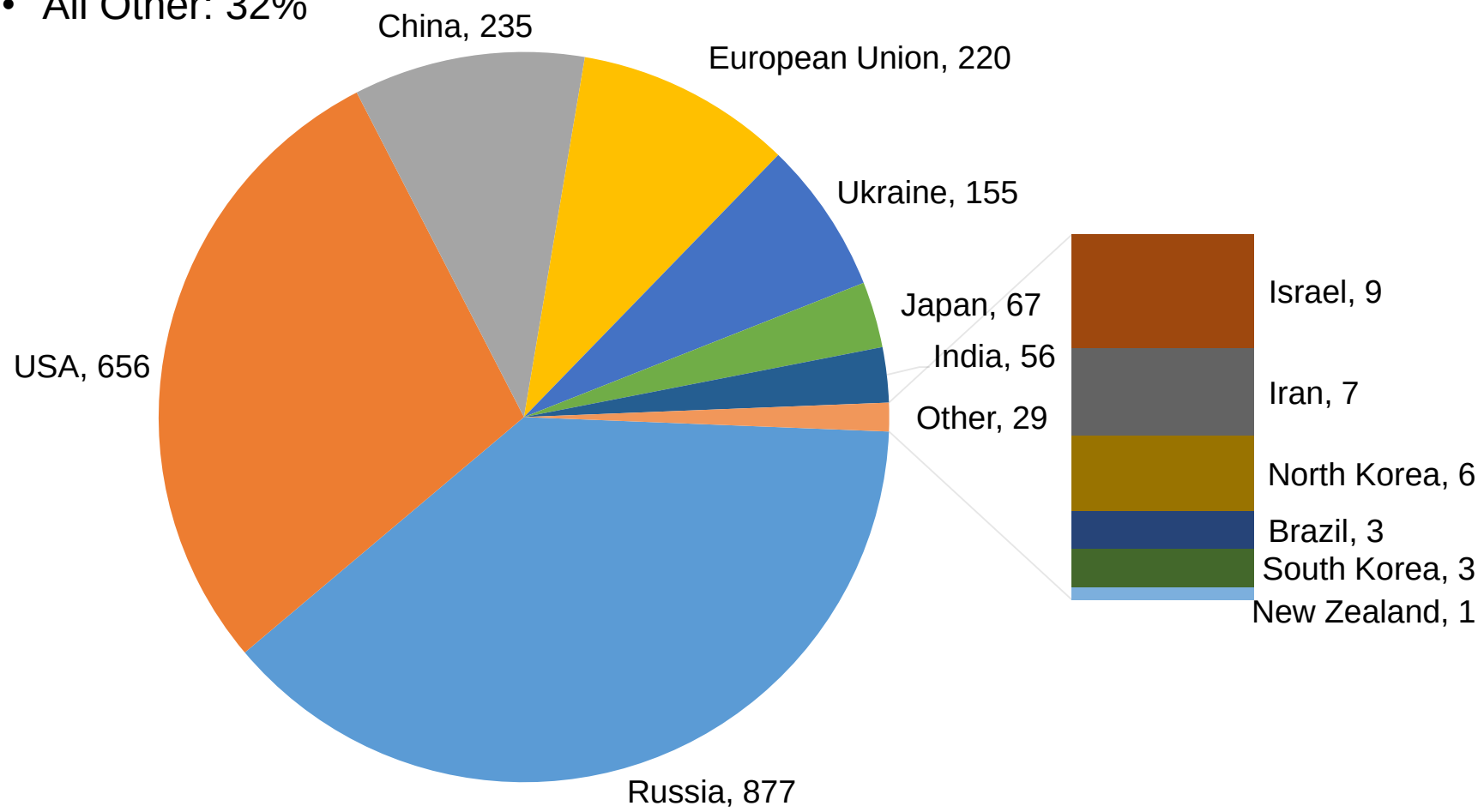
Global Launch Failure Rate





Number of Orbital Launches by Nation: 1989 - 2017

- **Total Orbital Launches: 2,309**
  - Russia: 39%
  - USA: 29%
  - All Other: 32%



Global Failures By System

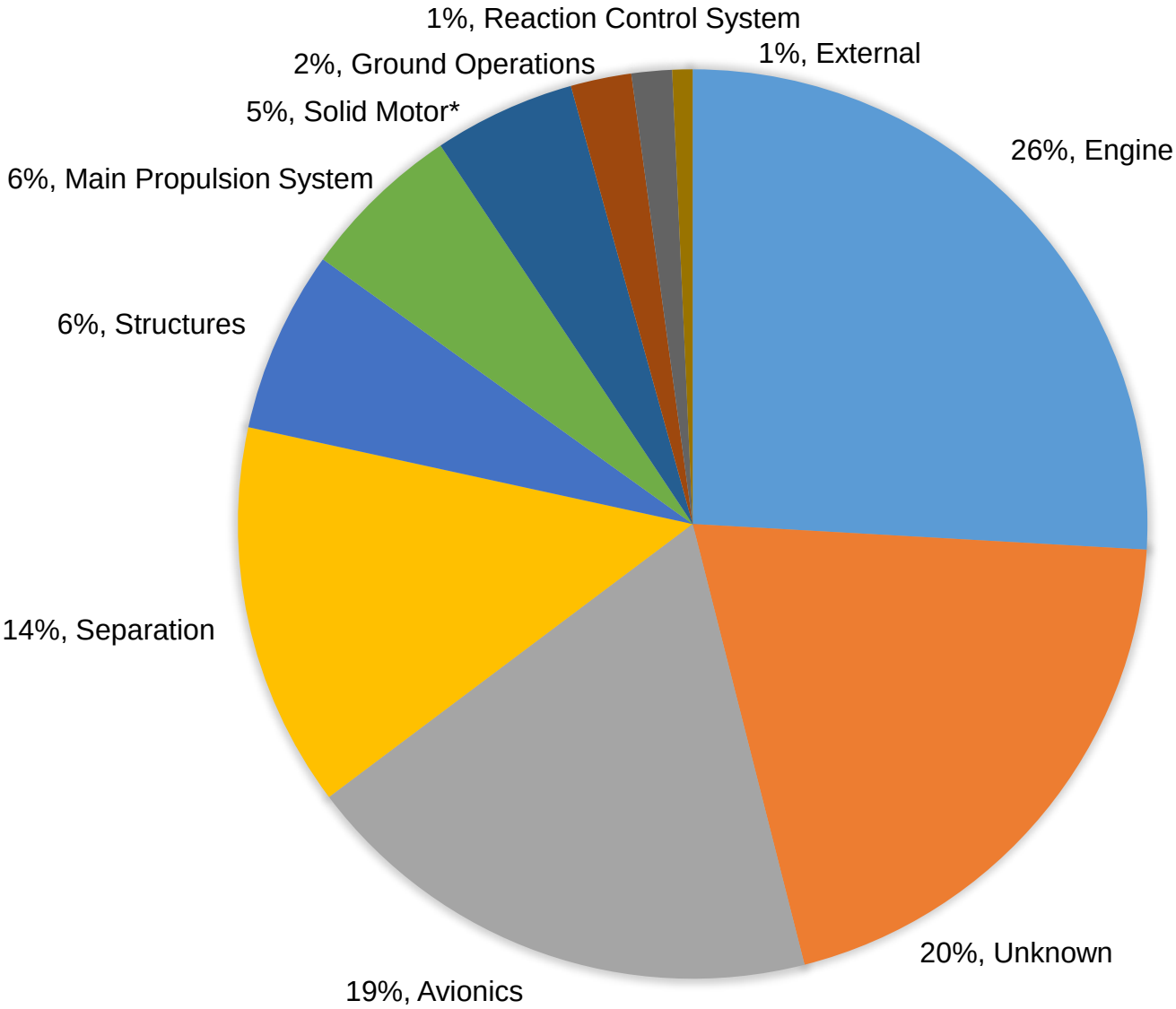
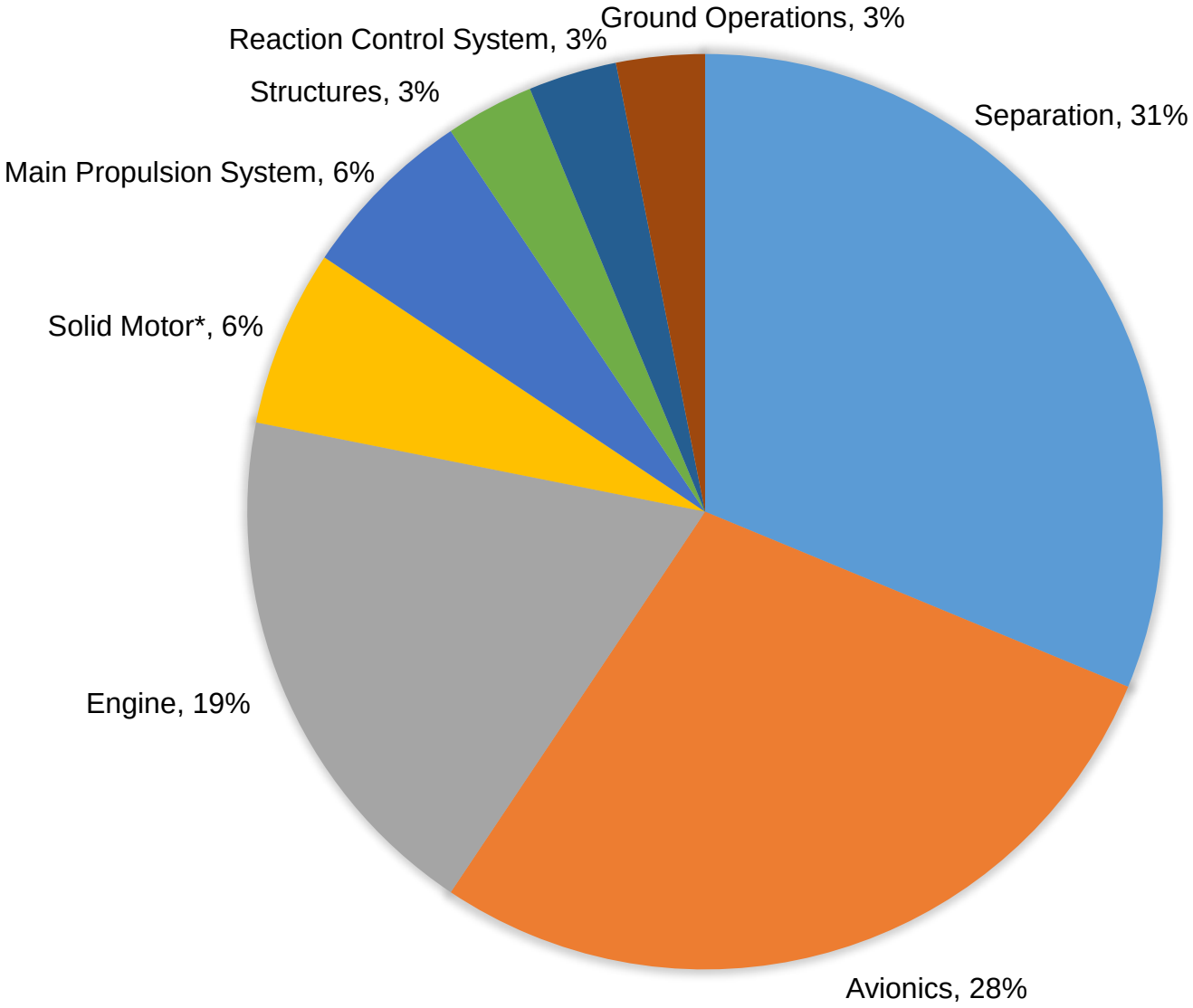


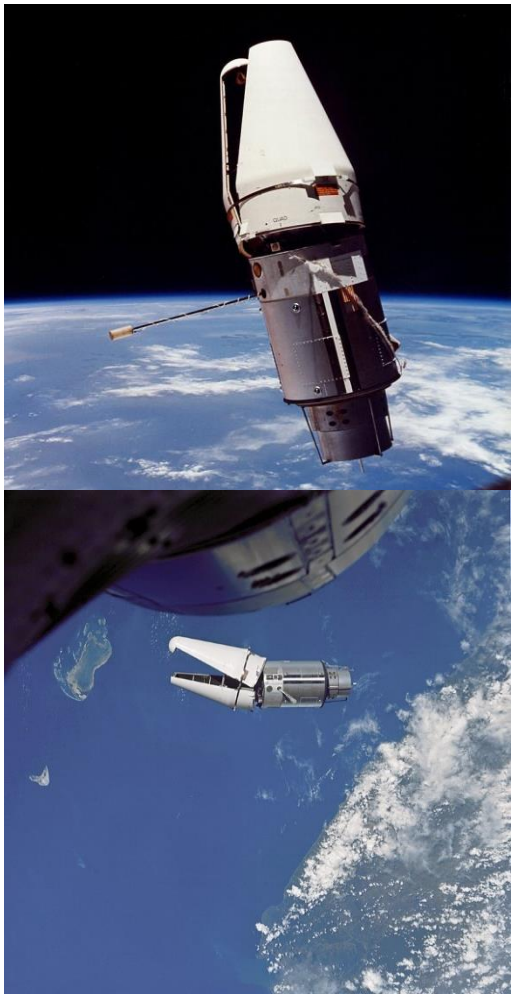
Photo: *SpaceX*, 2014

Falcon 9 launch failure
Photo: *SpaceX*, 2015

*Solid Rocket Motor not included on ALL launches

USA Failures By System



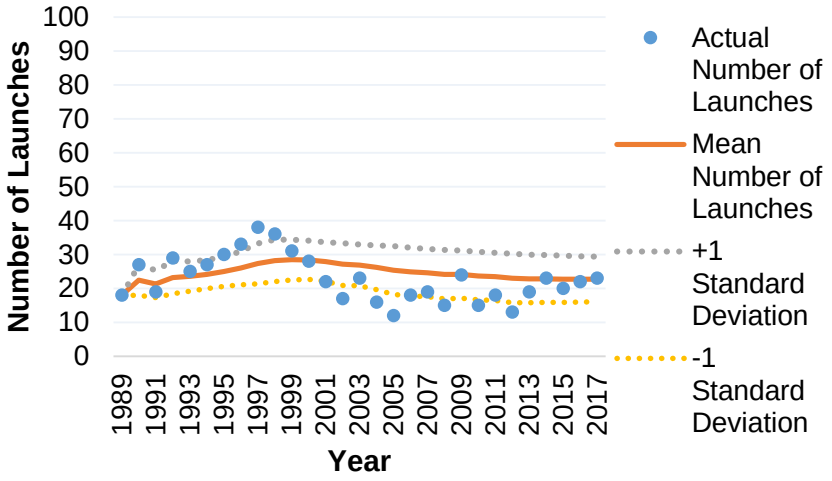


The Augmented Target Docking Adapter was successfully placed in orbit, but the payload fairing failed to separate
Photo: NASA, 1966

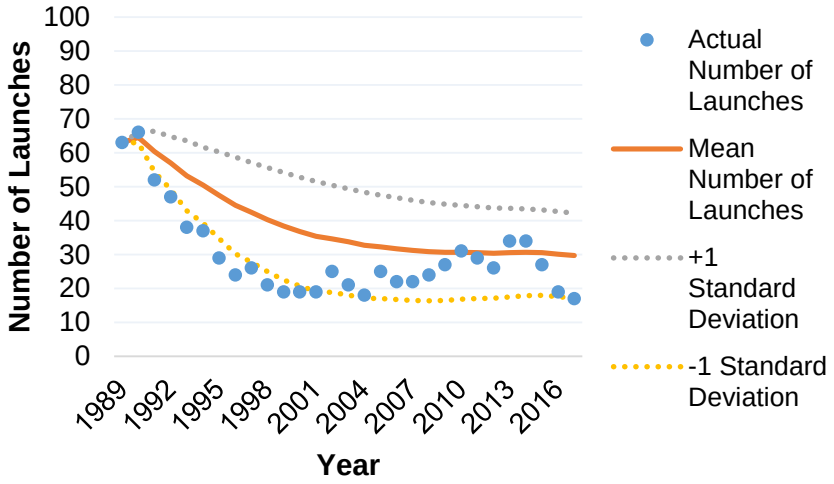
*Solid Rocket Motor not included on ALL launches

USA vs. Russia Launch Failure Rate

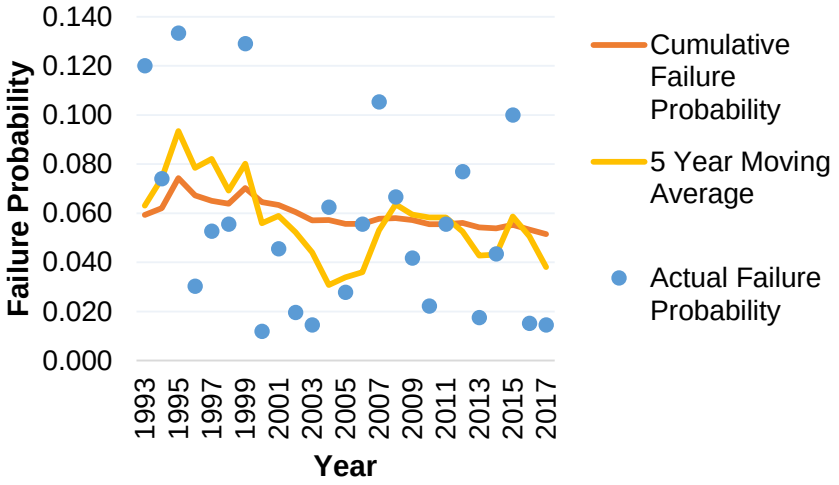
USA Number of Launches/Year



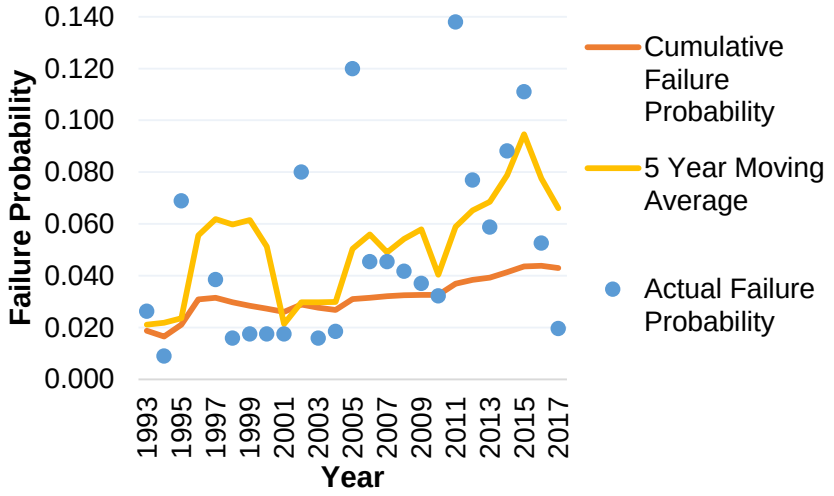
Russia Number of Launches/Year



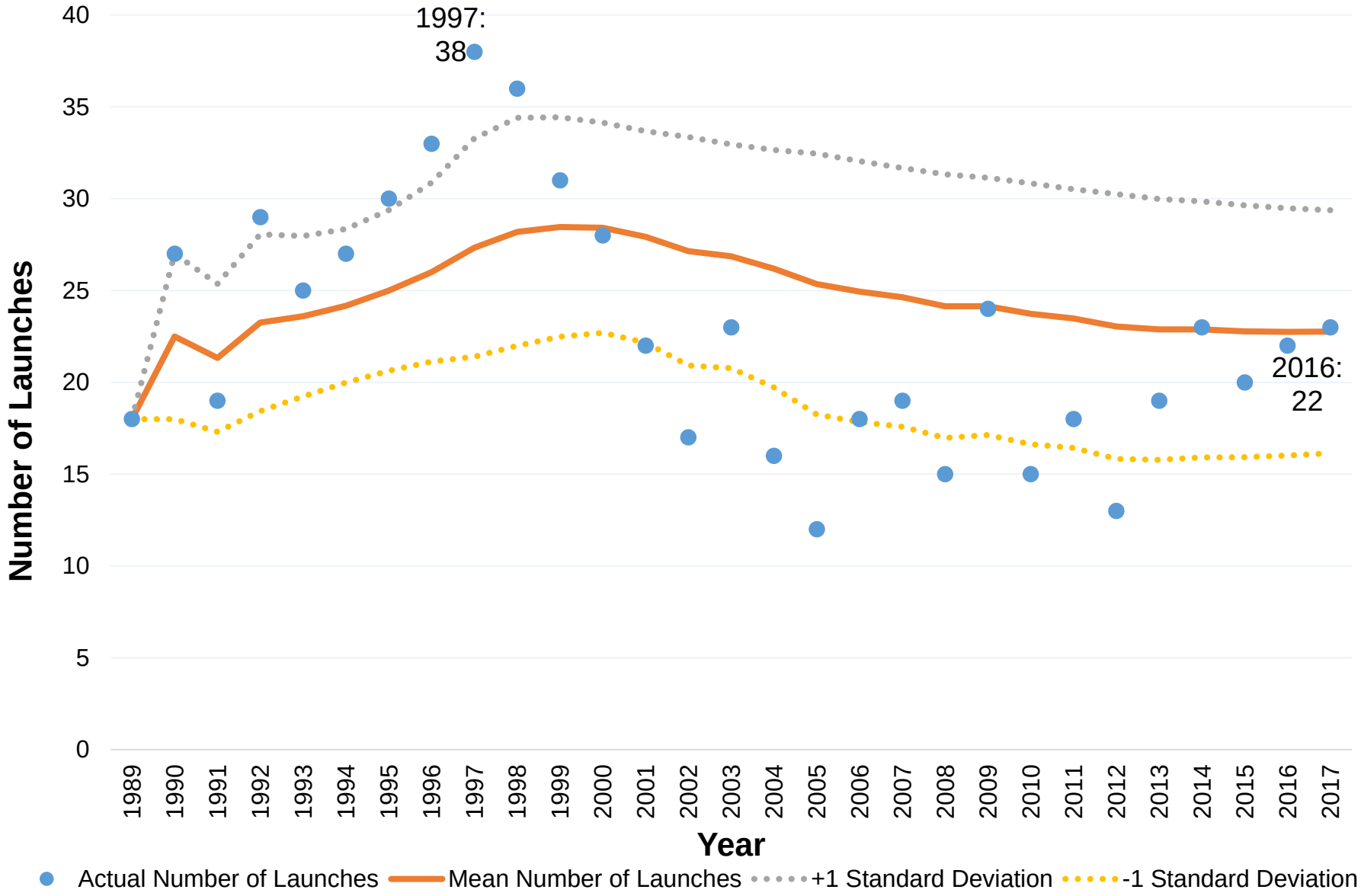
USA Failure Rate Moving Average



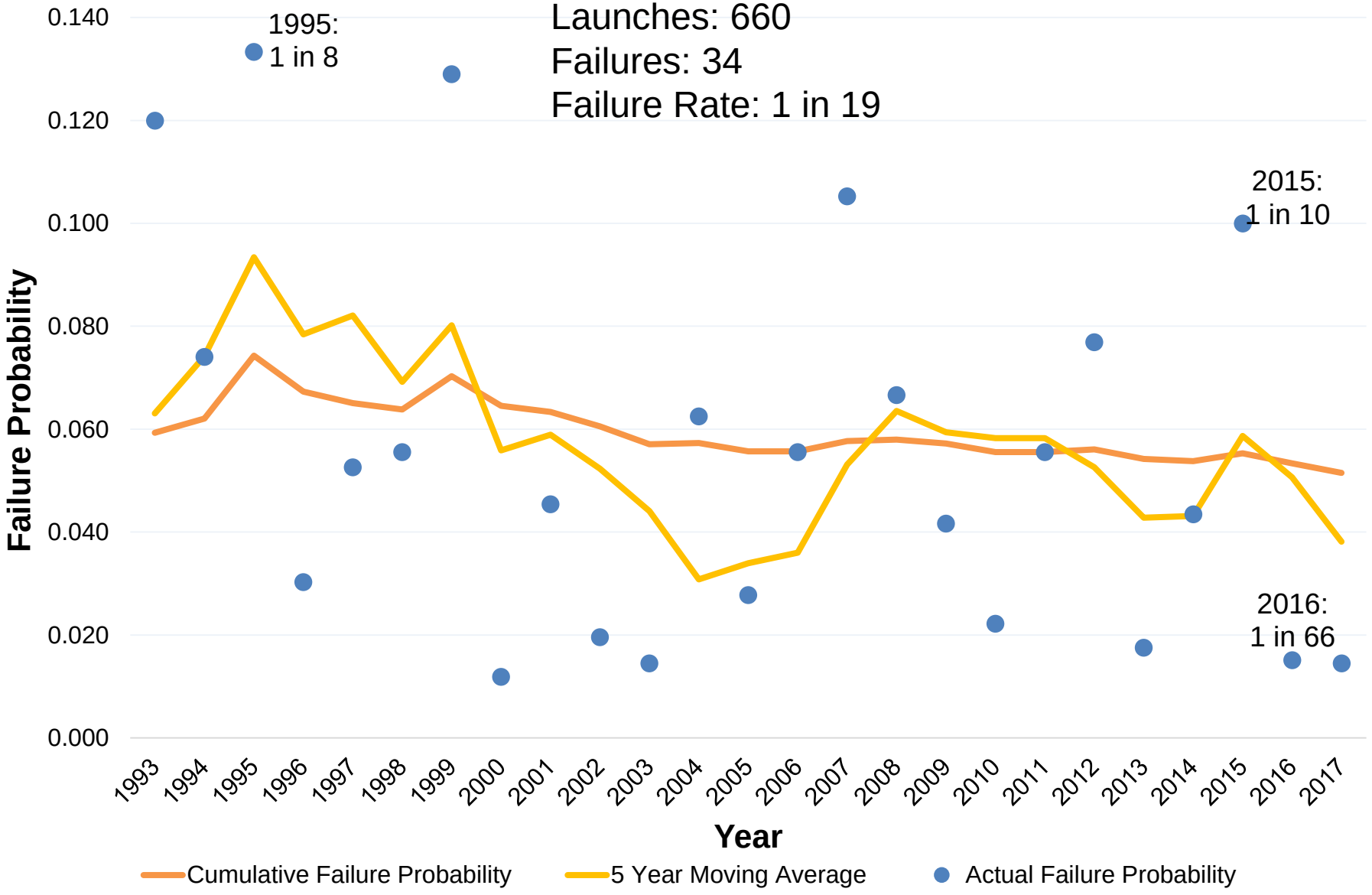
Russia Failure Rate Moving Average



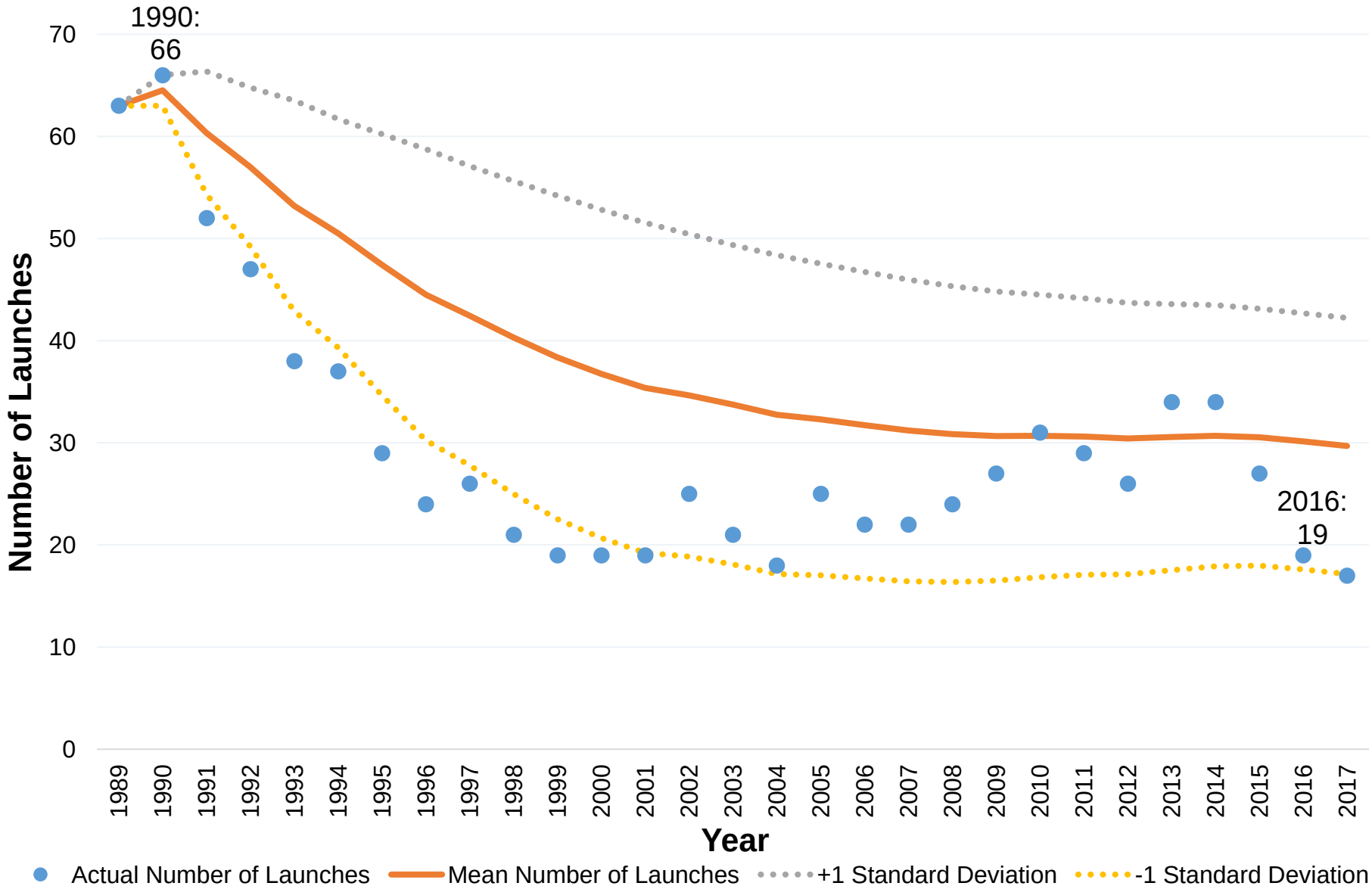
USA Number of Launches Per Year



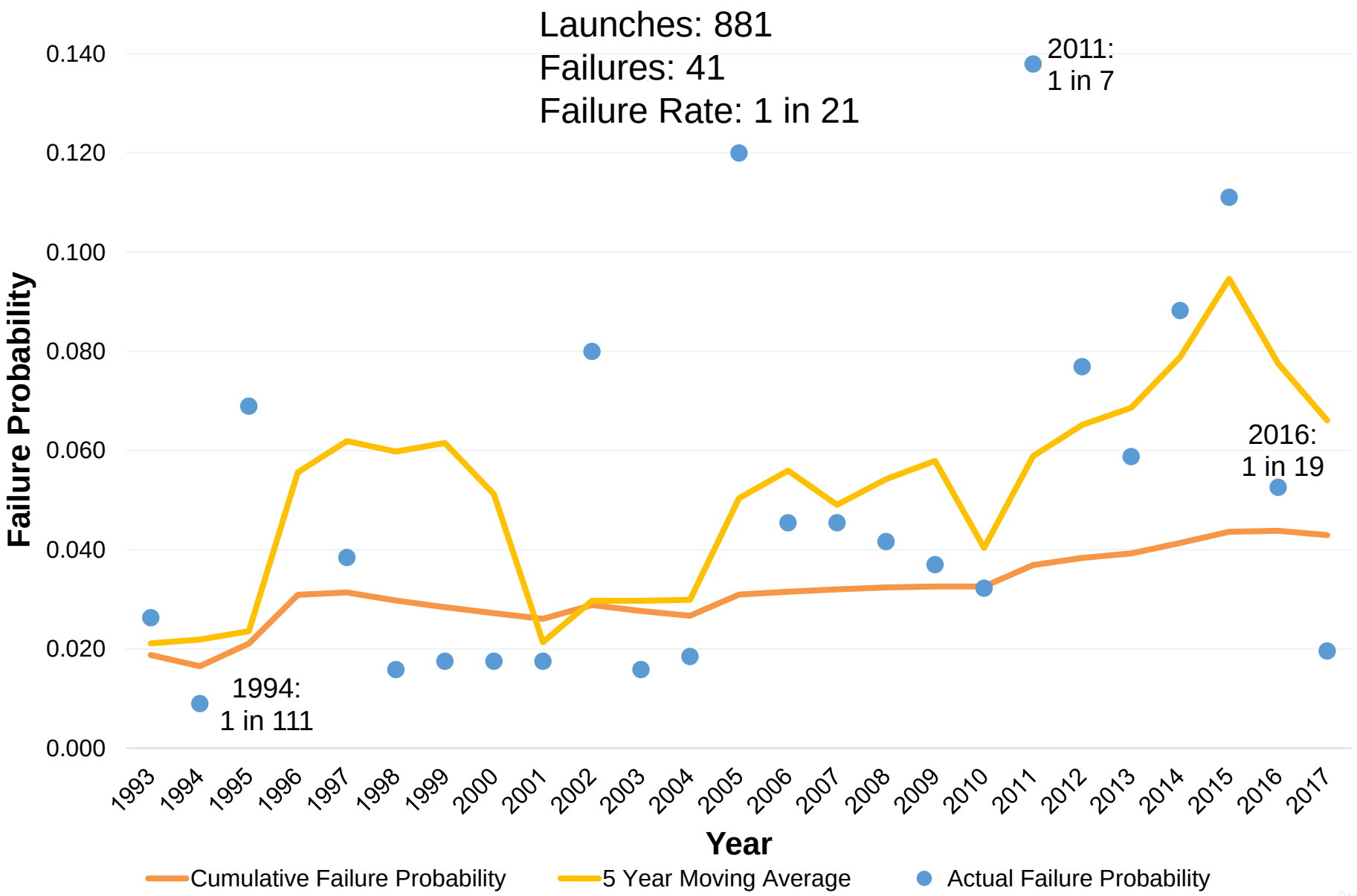
USA Failure Rate Moving Average



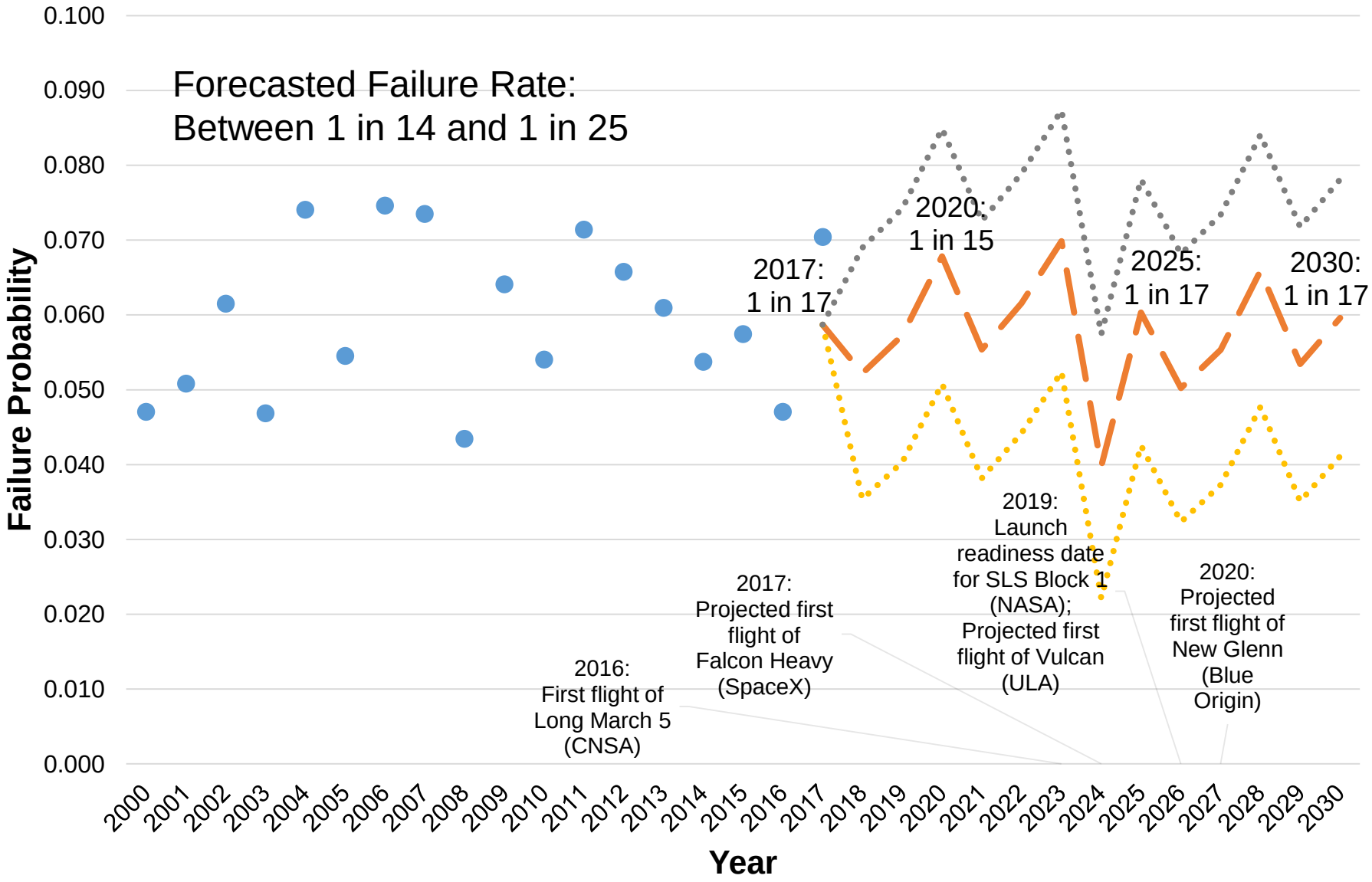
Russia Number of Launches Per Year



Russia Failure Rate Moving Average



Forecasting Global Failures



Trends

- **Rocket science is still a risky enterprise**
  - Currently only four of thirteen space-faring nations have launch failure probability lower than 1 in 10
  - Analysis indicates the global launch success rate is not dramatically improving and may be decreasing in some countries
- **Global yearly launch rate is increasing**
  - More nations are launching orbital rockets
  - Industry partners are preparing for commercial crewed, resupply, and deep space missions
- **Global failure rate is not expected to improve beyond 1 in 25 failures by 2030**

Future Work

- **Forecast improvements through:**
  - Acquisition of more data
    - Include data for ALL orbital launch vehicles (e.g. the Saturn class of launch vehicles was not included in this study)
    - Include data for suborbital launches (sounding rockets, missiles, etc.)
  - Incorporation of seasonality
  - Account for reliability growth
    - Discount first flights and test flights
  - Forecasting by launch vehicle class
  - Forecasting by launch organization
- **Launch failure probability comparison by payload**
  - Crewed missions, defense payloads for national security, commercial payloads, resupply payloads, and science/research missions accept different levels of launch risk
- **Launch failure probability comparison by quantity of critical subsystem or by lift capability**
  - The Falcon Heavy will fly with 27 liquid-fueled Merlin engines, whereas the Space Transportation System used three liquid-fueled RS-25 engines and two solid rocket boosters.

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