# Women in Space: From Historical Trend to Future Forecasts

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**Abstract:** In the history of space exploration, the gender balance has tended to favor men. However, the STEM (science, technology, engineering, and mathematics) fields have increasingly had women represented. This trend is often encouraged nowadays as openness to gender diversity in technology has been realized to be beneficial to the overall level of expertise in the fields, to the economy, and to those wishing to be part of these fields. Astronautics, the occupation charged with the direct human exploration of outer space forms an interesting case study.

Our study shows that the percentage of women throughout the world in the astronautics field and thus involved in space exploration has increased over time. This article explores the contribution of women as astronauts in terms of the percentages of astronauts that are women, the historical trend of increase in these percentages, and the extrapolation of the historical trend to provide foresight into future percentages. We are able to project, assuming the historical trend continues, the possible future increases in percentages of female astronauts worldwide.

## Introduction

Why should we be interested in whether women are counted among astronauts or not? One reason is the often-noted need for increasing numbers of women in science and technology. For astronauts in particular, if humankind is to expand into the cosmos without limits, self-perpetuating colonies will be necessary, making both male and female astronauts essential. This article explores the historical trend in women as astronauts and its extrapolation into the future.

### Historical Notes on Women's Involvement in Astronautics

Perhaps the earliest effort to put women in space was the 1959 WISE (Women in Space Earliest) program, which was initially cancelled but soon reconstituted as the Woman in Space Program which lasted until 1962 (Ryan et al. 2009). This led to a method for selecting female astronauts that was subsequently proposed and designed (Betson and Secrest 1964) but ultimately not implemented.

Ryan et al. (2009) note that the trend nowadays of women's participation in space has been related to national pride. The National Aeronautics and Space Administration (2017) discusses how exploring space has long been of great interest to humankind. Women have not participated in this exploration as much as men for various reasons. Women and men can see things differently and therefore can complement each other, yet their presence and full participation in the process has often been impeded by the "glass orbit" (Beall 2019), despite the fact that simulated spaceflight stress experiments on small groups comparing men and women found complementary responses across genders that have the potential to strengthen community problem-solving efforts (Sýkora et al. (1996).

Various other articles have discussed different aspects of the topic of women as astronauts. Individual profiles of female astronauts appear in Williamson (2021), Betz (2020), Space.com (2022), and Gibson (2014). The status of women in the space industry in general, not just as astronauts, is discussed in United Nations (2021), while the US Bureau of Labor Statistics (BLS Reports 2021) explores the wider labor market, providing context. A proposal for sending women to Mars, instead of men, is explained in Landis (2000), an idea expanded in scope in Nadia (2019). Some of the authors' personal experiences in undergraduate classrooms indicates that, with Mars as a destination, there would be plenty of volunteers.

### Motivation of the Study

Given the historical interest in women as astronauts, and the apparent growth in their involvement over time, we have conducted a data analysis to project the future levels of women in the astronautics profession.

### Data Analysis & Results

Some initial figures provide context by showing basic tabulations. The data is from McDowell (2022). These figures collectively indicate the disparity of women's involvement in space exploration.

Figure 1 shows the overall number of astronauts by gender as of the end of 2021. Figure 2 shows each year's percentage of male astronauts taking their first flights, out of the 100% total for all years from 1961 to 2021. Figure 3 provides the percentages of female astronauts' first flights for the years from 1961 to 2021. A gap between 1964 and 1981 is prominent, illustrating that women were not very active in the field during the initial period of the space age.

Figure 4 presents the numbers of female astronauts that have traveled into space by country. From the graph, clearly the USA has had more female astronauts than any other country.

Figure 5 is a chart showing the % of male and female astronauts' first space flights by year. The percentage of women traveling into space appears to be erratic but generally increasing.

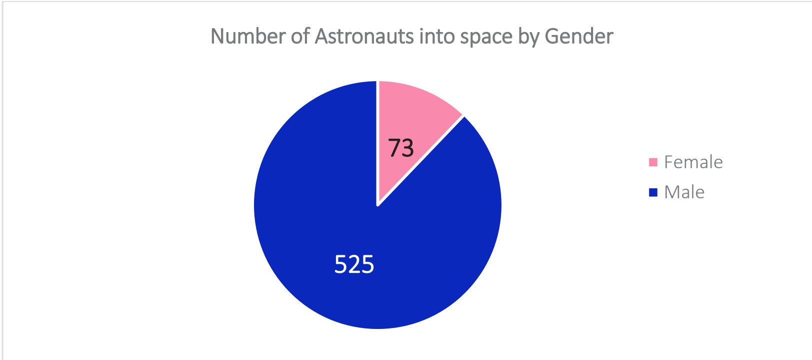


**Figure 1. Cumulative number of astronauts' first trips into space by gender.**

Similar to Figure 5, Figure 6 compares female and male astronauts by number from 1961 to 2021. From Figure 5 we can see that the % of women in space is relatively high for the year 2019 and 2006. However, the exact numbers were 4 and 6 respectively for years 2019 and 2006 (Figure 6), so the data is susceptible to random fluctuation due to the small totals, which likely played a significant role in the specifics for those and other years.

## A New Analysis

Figure 7 fits trend curves to the historical data, then extrapolates them to show possible futures. This approach was applied to other aspects of space exploration (Hall et al. 2017, Tsai et al. 2021), and here we apply it to astronaut gender percentages. We believe this analysis to be a new contribution.

Notice that near the beginning of the spacefaring era only one female astronaut flew her first flight (1963), and after that, astronauts' first flights into space were exclusively male from 1964 to 1981. After that the percentages of female astronauts' first flights shows a fluctuating tendency of increase. Nonlinear regression was applied to fit logistic curves to the data. The

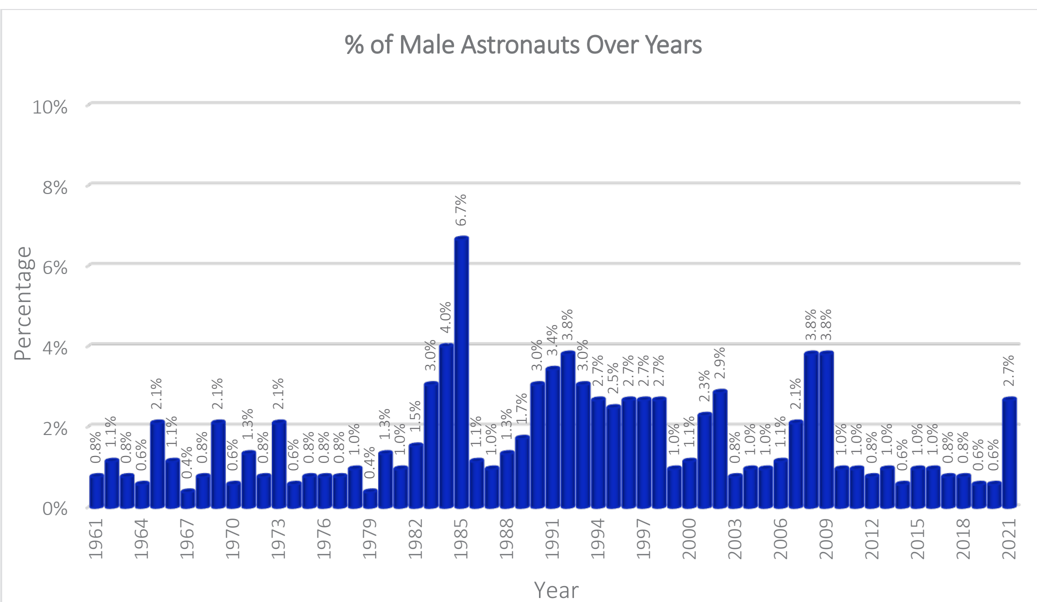


**Figure 2. Percentage of male astronauts by year of first flight.**

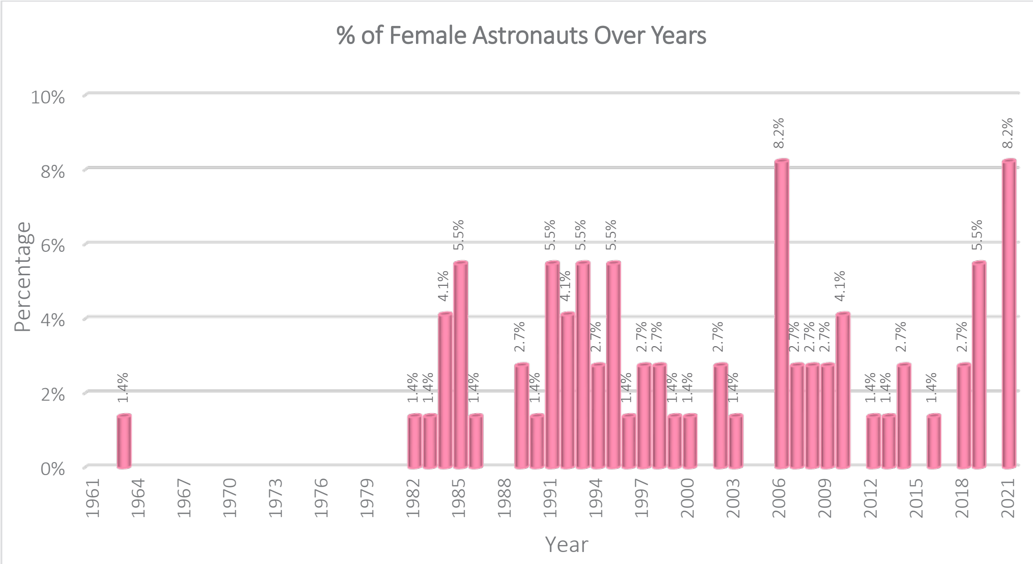


**Figure 3. Percentage of female astronauts by year of first flight.**

**Legend: CA: Canada, CN: China, F: France, I: Italy, J: Japan, KR: South Korea, RU: Russia (including Soviet Union), UK: United Kingdom, US: United States (Source: Wikipedia, List of female astronauts).**

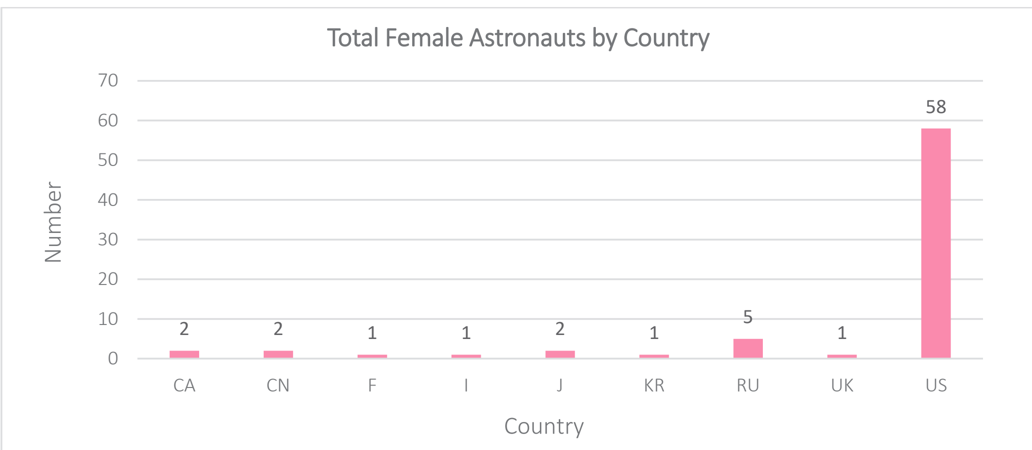


**Figure 4. Numbers of female astronauts by country.**

logistic curve, or S-curve, has the form:

$$f(t) = \frac{k}{1 + e^{-(t-t_0)/s}}$$

where $f(t)$ is the fraction of astronauts who are female, $k$ is the asymptotic maximum the function reaches on the $y$-axis, $s$ is the steepness (logistic growth rate), and $t_0$ is the inflection time point, which occurs at $k/2$ on the y-axis.

The lower curve in Figure 7 (red) was the best fit logistic, obtained by regression on all three logistic curve parameters $k$, $s$, and $t_0$ to find the values for them which minimize the summed squared residuals (SSR) between the data points and the curve. The value of $k$ is 0.23, reflecting

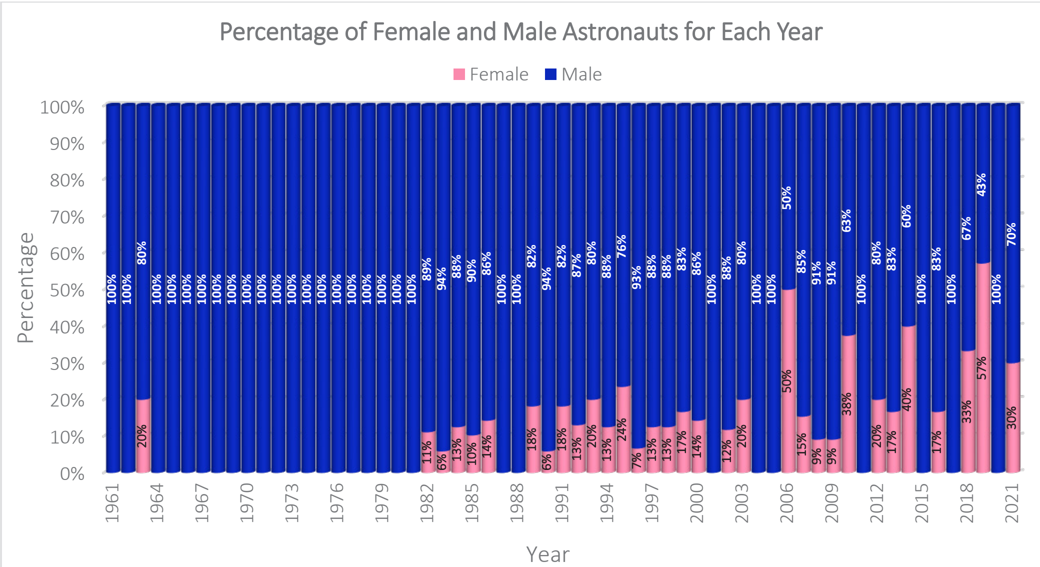


**Figure 5. Percentages of female and male astronauts by year.**

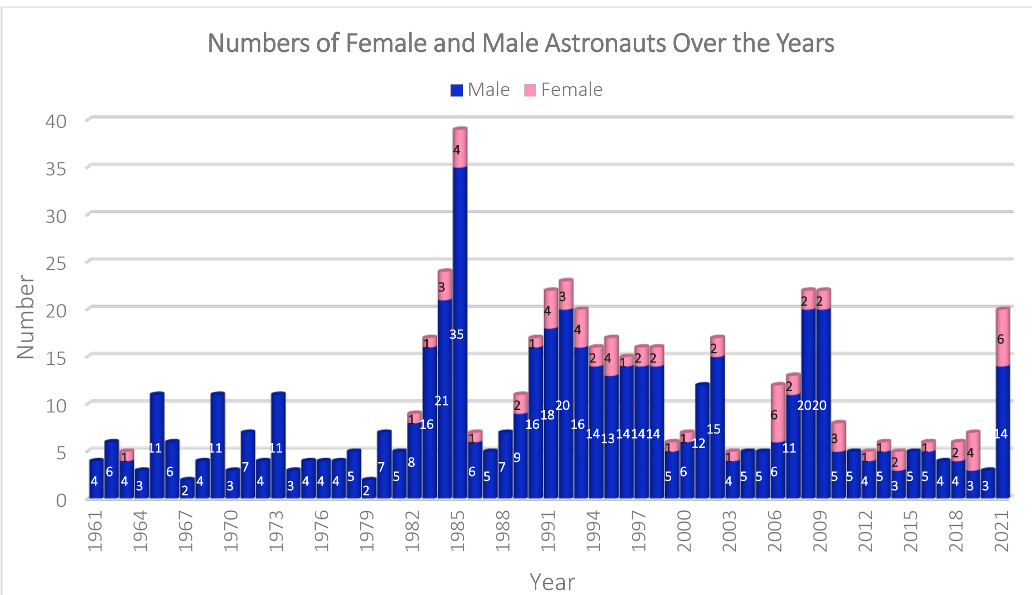


**Figure 6. Number of female and male astronauts by year.**

a future that ends with the percentage of female astronauts leveling off at 23%.

But what about the possibility of a future percentage that asymptotically levels off at 50%? The upper logistic curve (blue) is the result of forcing $k$ to 50% and regressing the other two parameters to the values that reflect a logistic curve that best fits the data under the constraint $k = 0.5$.

Although the two logistic curves are, as Figure 7 illustrates, quite different overall, within the time period for which data exists they are fairly close together. In fact, the measure of fit, the SSR (summed squared residual), is

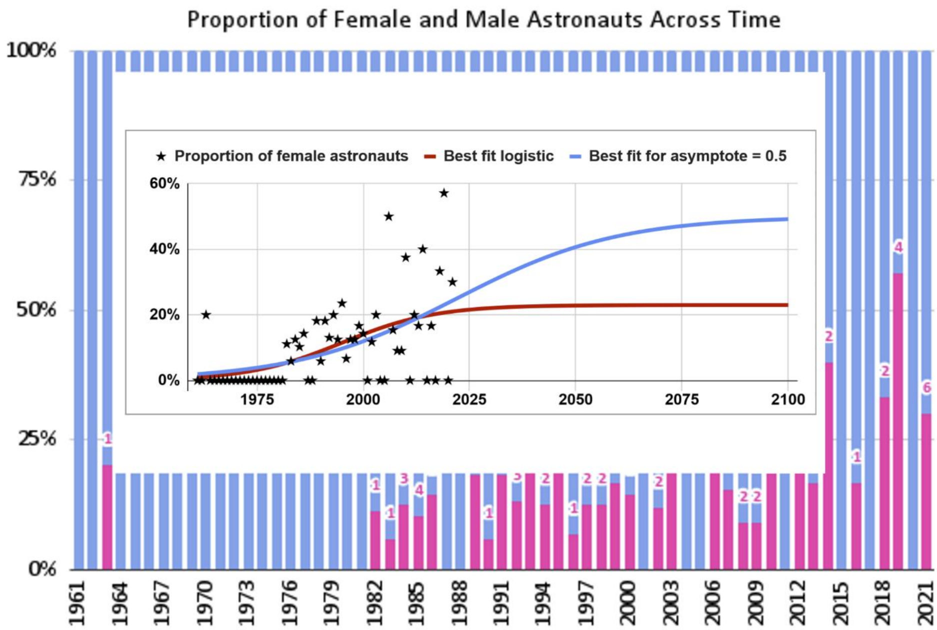


**Figure 7. Logistic curves regressed to the yearly percentages of female astronauts. The black star data points in the inset correspond to the heights of the pink bars in the background histogram.**

a mere 0.8% higher (worse) for the blue curve compared to the red curve. This indicates that the blue curve is almost as good a fit as the red curve, despite its much different asymptotic height, so although the blue curve is not the best fit it is well within the range of possibility (Berleant et al. 2003). Thus, the red curve is not destiny — the blue curve, projecting an eventual 50% female astronauts, is a plausible eventuality. The future values of the blue curve provide attainable yearly subgoals on the trajectory that according to the historical data is the most likely one to end at the 50% level. This is important to know since a long-term goal of self-perpetuating extraterrestrial colonies will require both male and female astronaut colonists, and the higher the percentage of female colonists the more robust the potential for population growth.

In Figure 8 the data is analyzed to show 95% confidence limits and 95% prediction intervals with an attempt to fit a second-order polynomial using statistical regression analysis with year as the independent variable to response F% over the forty-year time period between 1981 and 2021. All except two of the data points are contained with the 95% prediction interval but many of the data points lie outside the 95% confidence interval. The R-square value of 11.5% indicates that there is not significant regression between year and F% where F is defined as a ratio which compares the variation explained by the model (SSR) to unexplained variation (SSE). The result of this analysis of the data on the yearly proportion of male to female astronauts' first flights is that unexplained variation is a major factor in the overall participation of women in space over the forty-year period of 1981 to 2021.

## Discussion and Conclusion

Challenges encountered during the 21st century have led to rethinking and restructuring of society in many ways. Women's contributions to success in science and technology in general, and in space exploration in particular, have increased dramatically during this period, and numerous women were pioneers of some of today's widely used inventions (White House 2022). Yet obstacles to further increases remain

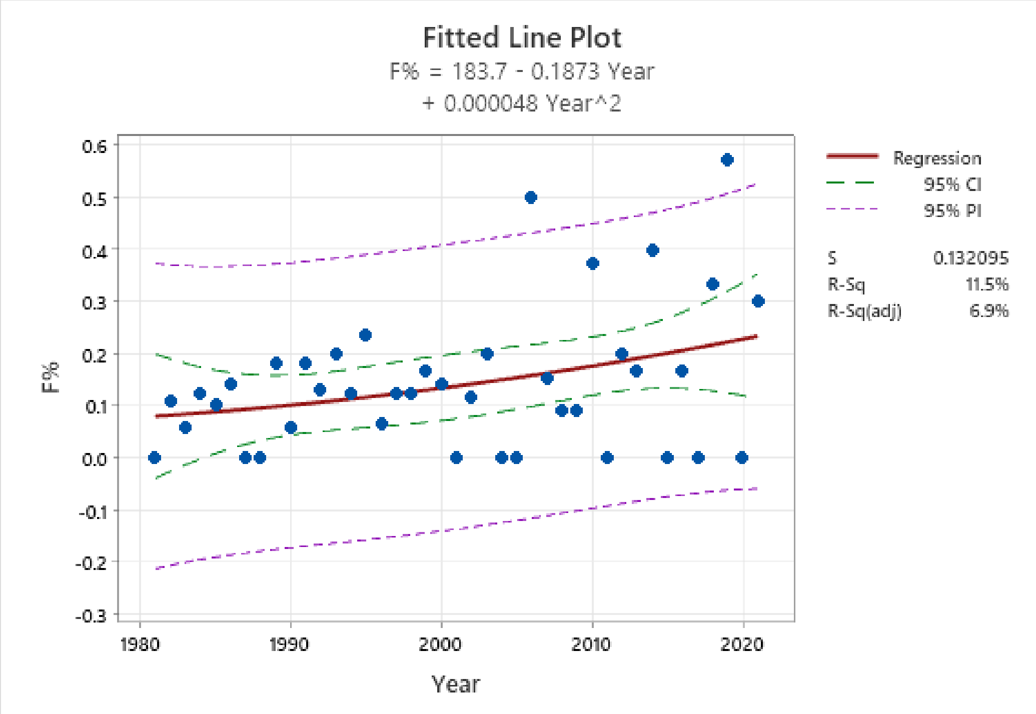


**Figure 8. A study of the proportion of male versus female participation in space activities. This shows both the confidence and predictions intervals for a polynomial regression.**

as challenges for society to alleviate, ranging from subcultural traits of particular fields to the need of society for child care. If society decides to commit to solving these problems, the benefits of increased contributions should follow. Such changes could enable faster and more effective progress in science and technology in general and space exploration in particular by ushering in further contributions by women participating and contributing to these fields.

The various graphs plotted have shown that women astronauts as a percentage of all astronauts was low early in the space age, but has been increasing in recent decades. We have contributed a new analysis in which the historical data record was regressed to a best-fit logistic curve which was extrapolated to identify two plausible trajectories for the future percentages of women astronauts. In the most likely scenario, the percentage of women as astronauts ultimately reaches 23%. Another likely scenario shows the most likely trajectory in which the level ultimately reaches 50%.

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