Solar Cycle Effects on Space Systems

THE solar activity cycle, as evidenced by the sunspot cycle is of interest to space systems because there is a high statistical correlation between sunspots and variations in terrestrial environmental parameters such as the density of the upper atmosphere, ionospheric perturbations, energetic charged particles in the magnetosphere, and cosmic-ray flux. These environmental variations have an impact on the operation of space systems since they affect satellite communications, orbital lifetimes, attitude control, electronic logic upset rates, spacecraft charging, total radiation dose, sensor backgrounds, ultra-low-temperature radiator performance, and a host of other operational concerns.

Thus far, the sunspot numbers of the present cycle, cycle 22, are much larger and rising at a faster rate than had been predicted on the basis of past solar cycles. In recent history, the sunspot maximum has alternated between a moderate maximum and a small maximum, with the even-numbered cycles being smaller. Cycle 19, which peaked in 1958, was the largest cycle on record (over 350 years). Cycle 20 was small and cycle 21 was intermediate between the previous two. Cycle 22 was generally predicted to be a small one. The latest sunspot data (April 1989) indicate that cycle 22 will be very much like cycle 19. The $F_{10.7}$ index, which is a relatively reliable *predictive* indicator, is currently following the cycle 19 pattern very closely. Figure 1 is a plot of 13-month smoothed $F_{10.7}$ data showing curves of the last three solar cycles plus dots for the portion of cycle 22 for which this index can be calculated (up to 6 months prior to the last available $F_{10.7}$ measurements). All indications are that cycle 22 will be as large as or larger than cycle 19 and may be the largest since reliable quantitative data became available.

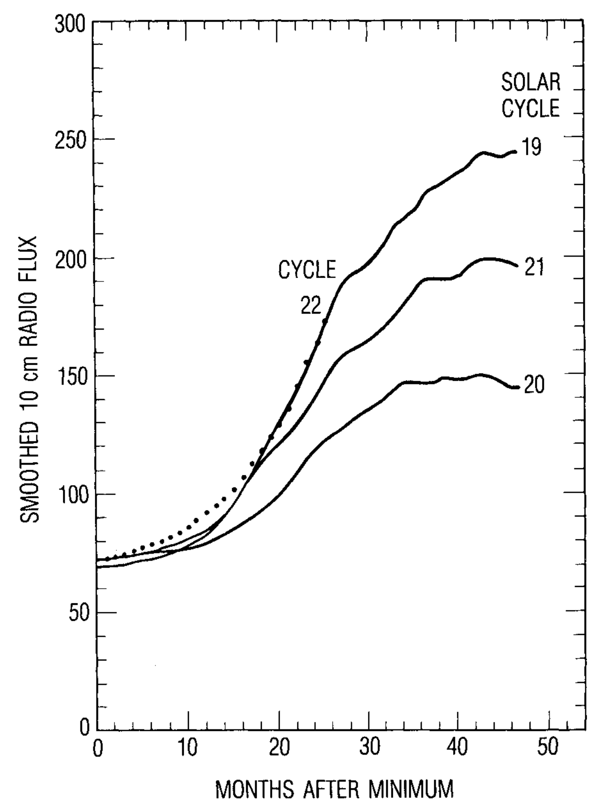

Fig. 1 Solar $F_{10.7}$ index.

The 1989 AIAA Aerospace Engineering Conference and Show included a session on solar cycle effects on space systems at which the following five invited papers were presented. In the first of these papers, "Solar Activity Cycle: History and Predictions," the history of sunspot observations, retrospective measurement techniques, predictive techniques, mechanisms of solar activity, and solar-geomagnetic energy coupling are discussed. The author then presents an analysis of the latest data and discusses the most reliable predictions for the remainder of cycle 22. The second paper, "Solar Proton Events During the Past Three Solar Cycles," presents a statistical analysis of solar cosmic ray events that have been observed during the last 30 years. The authors point out the problems that exist in the extended data set due to the evolution of instrumentation and observational techniques during the period of study. They find no significant correlation between the solar cosmic ray fluence and solar activity as evidenced by the size of the sunspot maximum. They conclude that the lack of a correlation may be due to biases in the data set and recommend a reanalysis of the source data.

The third paper, "Solar Cycle Effects on Trapped Energetic Particles," presents a short tutorial on the dynamics of particle acceleration in the magnetosphere, surveys the charged particle models currently in use (all of which were generated from data obtained during cycle 20, which was the least active of the last six cycles!) and then estimates the departures from the model environments that can be expected if cycle 22 is similar to cycle 19. The fourth paper, "Solar Cycle Effects on Near-Earth Plasmas and Space Systems," reviews the direct and indirect effects of solar activity on the near-Earth plasma environment, discusses the effects of variations in the plasma environment on spacecraft operations and communications, and then provides qualitative estimates of the effects of a solar cycle 22 that is similar to cycle 19. The final paper, "Solar Cycle Effects on the Upper Atmosphere: Implications for Satellite Drag," discusses the physics of solar-activity-induced atmospheric perturbations, their role in drag, and the order-of-magnitude variation in satellite drag over a solar cycle. The paper concludes that an enhanced cycle 22 would also result in drag that is enhanced compared with the last two solar maxima.

In addition to reviewing the current knowledge of solar cycle effects in the various areas, all of these papers also present new analyses—not because that was the original intent, but because the authors found that the literature in each area contained insufficient analyses of solar cycle effects. In several cases, these new analyses disclosed major areas where more study is required. The results and predictions presented in these papers should be of use to the spacecraft community during the remainder of cycle 22, which is expected to end in 1996.

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Guest Editor