

tracts" to "development and prototype contracts," and that the difference is substantial.

Coming now to question 35 from paragraph D(4):

What are the possibilities for establishing meaningful cause-and-effect relationships in the environment when longtime lapses occur in 20 to 30 years?

The essential requirements that must be met now if we are to do a good job in the future of understanding delayed cause-and-effect relationships are two: Collecting now adequate benchmark data in enough widely scattered environments, and rapidly improving our knowledge of relevant mechanisms.

On the biological side we can do much today in the way of useful benchmark measurements, though we have done very little. We could do much better soon if we work much more intensively both on how to make better measurements and on that better and deeper understanding of population dynamics that is needed to guide both what we measure and how we interpret it.

The physical example of the long-term changes in the CO_2 produced by burning coal, oil, and other fuel remains in the atmosphere illustrates the situation well. We are still unable to be sure what changes in climate will follow from this increase, though we expect to know soon, since the detailed mechanisms are being actively studied through computer simulation.

Mr. DADDARIO. How soon do you expect we can come to some judgment?

Dr. TUKEY. I would not pretend to be an expert on this. What I have been told suggests that we will know very much more within the next year or two. We clearly know much more about mechanism problems now than we did 2 years ago. We are making progress on this sort of scale. The essential feature is that, as is customary when you get into pollution, mechanism simulation is not simple. The investigation of models that treat only what happens in a vertical column of atmosphere has pretty clearly proved to be inadequate, both because the self-restoring properties of the atmosphere operate on larger scales than this and because the effects of CO_2 on the general motions of the atmosphere—on the so-called general circulation—may turn out to be the important ones. As a result, one has to look at fairly complex models in order to get a satisfactory idea of what is likely to be going on. We at least now do know about the input and we also, I think, know enough about general atmospheric mechanisms so that what is being put together will give a pretty good answer.

Mr. DADDARIO. And you believe that the establishment of benchmarks in this and other areas are important so that we can come to some judgment at the earliest possible date?

Dr. TUKEY. Yes, particularly, I think, in the biological area where it is not going to be enough to know where species occur. One has got to know something about the population density and things of this sort, because it is not going to be enough to be able to say these are the areas in which certain species have become extinct.

This in many cases is almost too late or even too late. We have got to be able to follow the biological phenomena that are involved in major changes in the pressures upon species, phenomena that are often going to be reflected in changes in species numbers, rather than in