IV. General Discussion

It remains to compare briefly the findings in the three animals and to bring these into relation with observations made by other investigators.

A comparison of the cardiac and respiratory variations is shown in Figures 24 and 25. It is seen that, in general, Old Reliable and Able reacted similarly to the main events in flight and quite differently than Baker.

The pre-launch period gave the best baseline record for evaluation of in-flight data. The transition at lift-off was the most useful event for purposes of comparison between flights. All three animals showed an initial rise in both cardiac and respiratory rate followed by a return to the baseline. This occurred while the acceleration was still very small, and it is altogether likely that the principal stresses were noise and vibration which had little or no direct effect on the circulation or breathing. In other words, this represented principally an emotional response. As such it was valuable information because it indicated to some extent the psychogenic component of subsequent responses. Thus the curves depicting heart rates showed steep brief rises in the case of Old Reliable and Able and a very brief rise followed by a prolonged fall in the case of Baker. The concomitant curves of respiratory rate showed small rises of moderate duration in the case of Old Reliable and Able and a large prolonged rise in the case of Baker. These reactions were interpreted as typical startle responses in the case of Old Reliable and Able and a more profound anxiety response in the case of Baker. The sustained rise in respiration and fall in heart rate have been interpreted as a response to "fright without flight" and this masked the response to the stress of acceleration.

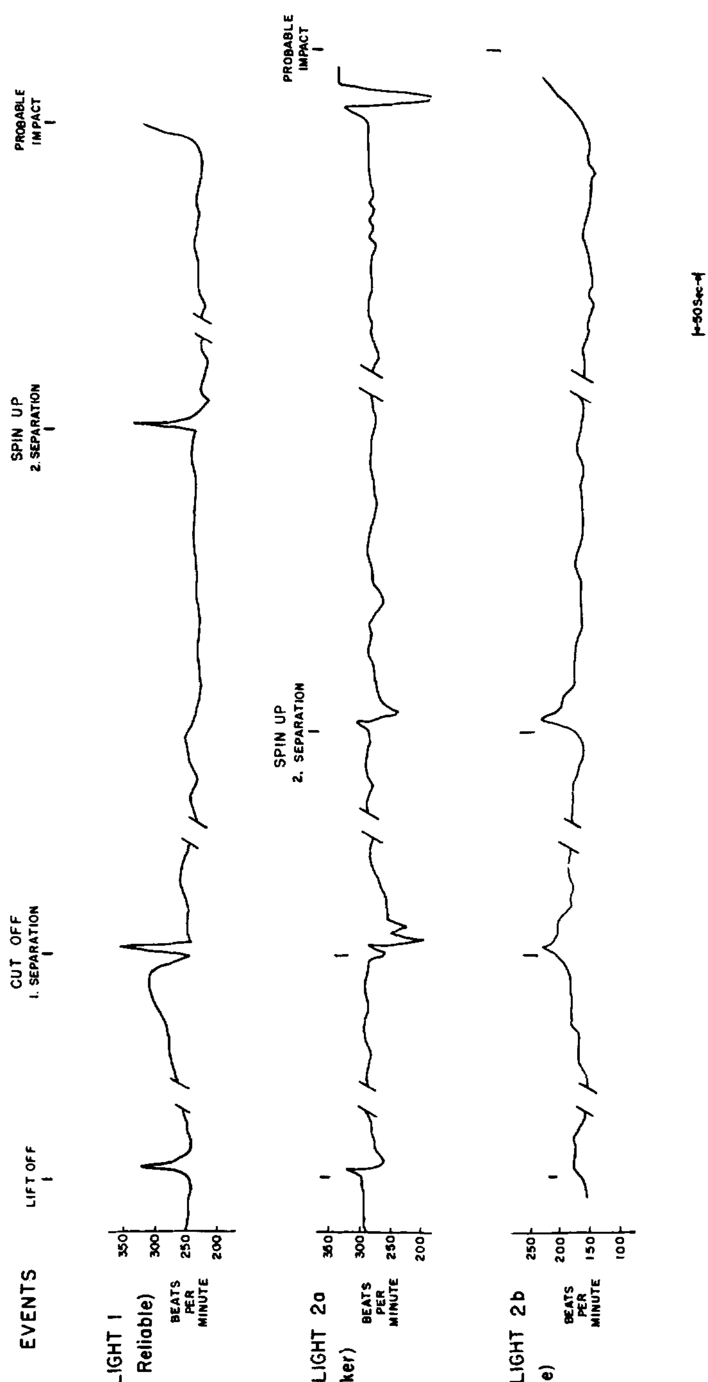

Fig. 24. Heart rate of three monkeys during Jupiter missile flights. Data curves have been interrupted but the time scale is accurate for segments shown.

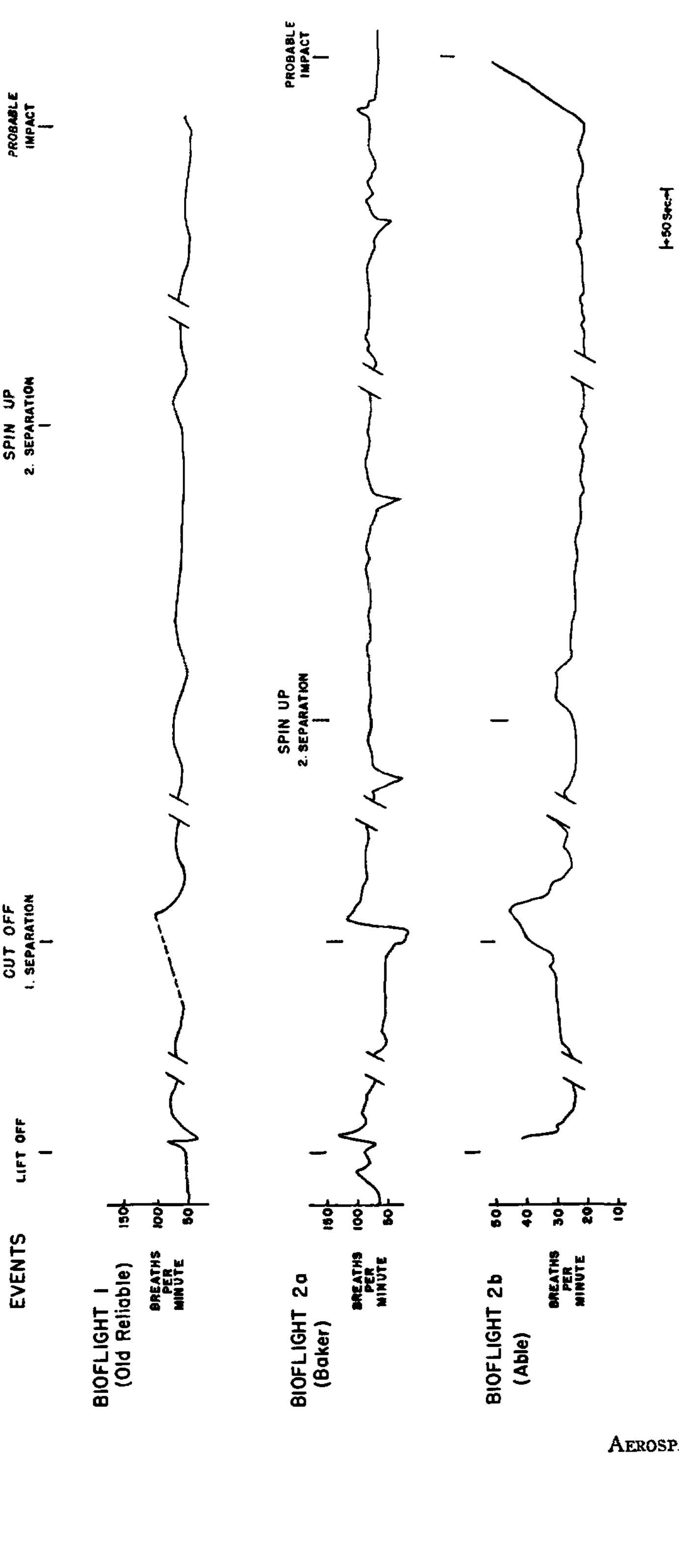

Fig. 25. Respiration of three monkeys during Jupiter missile flights. Data curves have been interrupted but the time scale is accurate for segments shown.

During the continuing period of acceleration, the curves depicting the cardiac and respiratory rates for Able rose and followed a pattern roughly similar to that depicting acceleration. In the case of Old Reliable,* the curve depicting heart rate was similar to that for Able except for a sharp fall during peak acceleration. In the case of Baker, if it is assumed that the cardio-inhibitory influence persisted until heart rate returned to the usual level, then the response to acceleration was insignificant until peak acceleration when the rate fell abruptly as in the case of Old Reliable. If the same allowance for the emotional response is made in considering respiratory rate, this abrupt fall was almost certainly a direct effect of acceleration on the cardiorespiratory system.

Individual differences have been noted by others even when it involved animals of the same species in the same flight.[2,8,9] Kousnetzov[6] has reported that the famous dog Laika experienced an increase in cardiac and respiratory rate during the burn-out phase in *Sputnik II.* Pokorovski,[7] in summarizing the experiments carried out in Russia in sending dogs aloft in the nose cones of rockets states: "During the powered part of the flight, both an acceleration and deceleration of the pulse rate was observed. In the majority of cases, the pulse rate increased by thirty-two to fifty-six per minute, in one case it remained practically unchanged and in three cases it decreased by six to sixty per minute." He emphasized the fact that this could only be explained on the basis of individual differences but did not speculate on the mechanism responsible for these differences. Pokorovski also stated that respiration usually increased but that in two cases it decreased. He does not state whether these dogs also had a decrease in heart rate. Henry and his co-workers,[4] who sent anesthetized monkeys aloft in the nose cone of V-2 and Aerobee rockets, reported rather small changes in cardiac and respiratory rates during the boost stage. These and other observations[9,10] support the conclusion that the typical response is an increase in cardiac and respiratory rate, but occasionally a decrease is recorded.

During the transition from boost to zero acceleration three factors were operating, namely, the residual effects of acceleration, the emotional reaction to the change, and the new state of weightlessness. It is worth noting that the magnitude of the responses in the three animals paralleled that of the responses at lift-off. Old Reliable reacted sharply but briefly with a rise in heart rate and a fall in respiratory rate from a previously elevated but unknown level. It suggested a reaction to the previous acceleration plus a startle response; the quick return to the usual levels indicated that weightlessness *per se* was not an effective stimulus. Baker exhibited a very striking, sudden increase in respiratory rate representing almost surely a release from the pressure on the thorax due to acceleration. The concomitant increase in heart rate was very brief and not higher than the usual level. Thereafter, the response was similar to that after lift-off only in a more exaggerated form. It was

*The respiratory signal during the acceleration period failed with Old Reliable.

interpreted as an emotional reaction which masked any physiological responses to weightlessness.

Able reacted with a brief slight rise in cardiac and respiratory rate superimposed on the already elevated levels resulting from the boost. This was followed by a slow return to prelaunch levels after which fluctuations ensued. The response certainly contained an effect due to startle and possibly reactions to the new state of weightlessness.

The cardiorespiratory changes following the transition from acceleration to the subgravity state have aroused much interest. The Russians have reported that the tachycardia experienced by the dog Laika on transition from boost to zero G required three times as long to subside as it did in simulated acceleration tests in the laboratory. The Russians have also reported that dogs subjected to repeated missile flights have shown progressively smaller responses, indicating adaptation. The "typical" response is regarded as an increase in cardiac and respiratory rate with fluctuations thereafter finally stabilizing at about control values. However, a few exceptions to this have been reported.[1,6,10] Von Beckh[10] has emphasized the tendency of alternate periods of weightlessness and acceleration to decrease tolerance to those states as indicated by loss in efficiency of the physiological recovery mechanisms.

Spin-up might have produced effects due to startle, stimulation of the semicircular canals associated with movement of the body (head), and acceleration. The last differed in that Old Reliable and Baker, remote from the center, were subjected to a substantial radial accelerative force whereas Able near the center experienced little. In other words, Able did not experience any significant change from the zero G state until re-entry but the others did.

Following spin-up, there was a brief but conspicuous rise in heart rate in Old Reliable and Able, but in Baker a slight brief rise was followed by a prolonged fall. Respiration rose slightly in the case of Old Reliable and Able but in Baker a change was not identifiable. The reactions might well have been psychogenic in origin.

On re-entry, the signal was lost early in the case of Old Reliable but not before a rise in heart rate occurred. Able showed a striking increase in both cardiac and respiratory rate. Baker developed cardiac inhibition with sino-atrial block but exhibited little change in respiratory rate. The response at re-entry appeared earlier in the case of Able than of the others, possibly because the transition was from zero G. There was nothing to indicate startle—possibly because of the gradual onset of change. With Baker, cardiac slowing was cut short. Without doubt the responses due to the action of physical forces on the body were predominant.

Following the readjustments after cut-off, all three animals eventually established fairly stable cardiac and respiratory rates not far from prelaunch values. This is in keeping with the observations of others, and it is reported that Laika tolerated the weightless state very well for at least seven days after which signals were lost.

Disorientation appeared not to be a problem in this experiment. During the weightless state there was evidence that Old Reliable moved frequently, but his activity did not decrease after spin-up introduced a G component. Moreover, both Able and Baker were quiet during much of the time. This may well have been different had the monkeys not been restrained and thus furnished contact cues. It has been shown[3,5] that animals free to move under zero G conditions tend to struggle and claw the air seeking a foothold but remain comparatively quiet when restrained. Also, there was no evidence that the animals were greatly disturbed as the result of head movements which stimulated the semicircular canals during the period of constant rotation. At least we know that Able and Baker did not vomit. Moreover, spin-up, after initial transitory effects had passed, did not result in a significant change in pattern of cardiac or respiratory variations and did not cause a sudden increase in body movements.

Some of the data still await analysis, but the additional results are expected to supplement and not alter the findings which have been described. Certain aspects of our findings are directly applicable to man and some are not. The success in providing and monitoring a satisfactory atmospheric environment means the same could be done for man. The success in providing adequate protection against physical forces of flight have only small application for man, although they cast some light on the larger problem.