Estimating human error rates in the aerospace industry, particularly for aircraft crews, is a complex endeavor. It’s influenced by factors like training, experience, workload, cockpit design, procedures, and organizational culture. There is no single, universally accepted “human failure rate” that applies to all situations. It is context dependent. However, we can provide some representative figures and references that illustrate the order of magnitude and how these rates are derived:

**General Ranges and Concepts:**

* **“Nominal” or “Baseline” Human Error Probabilities (HEPs):** These are starting points. A common range for relatively simple, well-trained tasks is often considered to be around **0.001 to 0.01** (1 in 1000 to 1 in 100). This means there’s an estimated 1 to 10 chances out of a thousand that a single well-trained individual will make an error on a relatively routine task performed under nominal conditions. For skilled behavior and nominal stressors.
* **Stress and Complexity Increase Error:** Error rates increase significantly under stress, fatigue, poor lighting, high workload, and poorly designed procedures. The HEP can easily jump to **0.01 to 0.1** (1 in 100 to 1 in 10) or even higher in such circumstances.
* **Dependence:** If multiple crew members are involved, the errors aren’t necessarily independent. “Common mode failures” can occur where a single event or condition causes multiple individuals to make similar errors. Dependency can greatly increase failure probabilites.
* **Recovery:** Error rate *probabilities* are also heavily impacted by the likelihood of error recovery - i.e., detection of an error before it leads to a failure event.

**Specific Examples and References:**

It is VERY important to note that directly applying these figures in a different context is generally incorrect. Instead, they should serve as starting points for further task and context-dependent analysis, which can be done through techniques like HEART (Human Error Assessment and Reduction Technique).

1. **THERP (Technique for Human Error Rate Prediction):** THERP is a widely used method for estimating human error probabilities. It uses a database of generic human error probabilities for various tasks and modifies them based on performance shaping factors (PSFs). Although THERP data is proprietary, some examples can be found in public literature.
   * **Reference:** Swain, A. D., & Guttmann, H. E. (1983). *Handbook of human reliability analysis with emphasis on nuclear power plant applications. Final report.* NUREG/CR-1278. [This is the classic reference, but hard to find. Search for discussions of THERP online.]
   * **Example:** A simple reading task with a clear display might have a HEP of 0.001. If the lighting is poor, the HEP could be adjusted upward using a performance shaping factor.
2. **HEART (Human Error Assessment and Reduction Technique):** HEART provides generic error probabilities for different error producing conditions (EPCs).
   * **Reference:** Williams, J. C. (1988). HEART—a proposed method for assessing human error probabilities. *Reliability Engineering & System Safety*, *22*(1-4), 285-296.
   * **Example:** “Completely unfamiliar action” has a higher error probability than “skilled, routine task”. HEART guides analysts to select the most appropriate EPC and then adjust based on the task complexity and PSFs.
3. **Specific Aircraft-Related Studies (Examples):**
   * **Boeing studies** may publish data related to pilot error in specific accident reports or safety analyses, but this data is usually not directly released as a generic failure rate.
   * **Airbus studies** have published guidance material for human factors design and safety assessment.
   * Look for reports from the **National Transportation Safety Board (NTSB)** or equivalent aviation safety agencies in other countries. These reports often analyze the contributing factors to accidents, including human error. While they don’t typically give a single “failure rate,” they do highlight common error types. The FAA also offers information about human factors.
4. **Other Resources:**
   * **Human Factors Engineering Handbooks:** These handbooks often contain general information about human performance and error. Search for handbooks related to aerospace or aviation.
   * **Academic Journals:** Journals like *Reliability Engineering & System Safety*, *Human Factors*, *Ergonomics*, and *Journal of Air Transport Management* publish research on human error and reliability.

**Important Considerations:**

* **Context is Critical:** Never apply a generic error rate without carefully considering the specific task, environment, and crew involved.
* **PSFs (Performance Shaping Factors):** Always identify and account for performance shaping factors that could increase or decrease the likelihood of error.
* **Task Analysis:** A detailed task analysis is essential to understand the steps involved and identify potential error points.
* **Training and Procedures:** The quality of training and the clarity of procedures have a significant impact on human error rates.
* **Data Limitations:** Data on human error is often limited and may be based on simulations, expert judgment, or accident investigations. Therefore, you may not have enough failure data to support calculating a failure rate.
* **Qualitative Data:** In such situations, it may be better to rely on qualitative risk assessment approaches such as HAZOP (Hazard and Operability study).

**In summary:** It is difficult to give a single, accurate “human failure rate” for aircraft crews. Instead, risk analyses in the aerospace industry should use techniques like THERP or HEART to estimate error probabilities based on specific tasks and conditions, taking into account factors such as training, workload, and environmental stressors. Always consult multiple sources and exercise caution when interpreting and applying human error data. Focus on risk analysis techniques as a path toward understanding risk.

Neither exponential nor Weibull distributions are generally considered appropriate for modeling *human error rates* directly in the same way they’re used for mechanical or electronic component failures. Let’s break down why and discuss better alternatives:

**Why Exponential and Weibull Are Problematic for Human Error:**

* **Constant Failure Rate (Exponential):** The exponential distribution assumes a *constant failure rate*. This implies that the probability of a human making an error is the same regardless of how long they’ve been performing the task, how many times they’ve performed it successfully, or their experience. This is demonstrably false. Human performance improves with experience and is affected by factors that change over time (fatigue, stress, etc.). An exponential distribution also does not account for learning or decay in performance, which are key features of human performance.
* **Weibull’s Limitations:** While the Weibull distribution offers more flexibility (allowing for increasing, decreasing, or constant failure rates), it still doesn’t capture the complexities of human error. The shape parameter in the Weibull would be difficult to justify based on actual human performance data. It’s challenging to map the physical degradation that drives Weibull in mechanical systems to the cognitive and psychological factors influencing human error.
* **Human Error is Not Purely Random:** The exponential and Weibull distributions are rooted in the concept of random failure. While there’s a degree of randomness in human behavior, error is far more often systematic, influenced by factors like:
  + **Design flaws:** Poorly designed interfaces, procedures, or training.
  + **Organizational factors:** Poor communication, inadequate supervision, or a culture that doesn’t prioritize safety.
  + **Performance Shaping Factors (PSFs):** Stress, fatigue, workload, environmental conditions, etc.
  + **Cognitive Biases:** Systematic errors in thinking.

**Better Approaches for Modeling Human Error in Risk Analysis:**

Instead of directly forcing a distribution onto a “human failure rate,” here’s how human error is typically handled in probabilistic risk assessment (PRA) and human reliability analysis (HRA):

1. **Discrete Probabilities (Event Trees/Fault Trees):** The most common approach is to represent human actions as discrete events in event trees or fault trees. Each human action is assigned a probability of failure (HEP - Human Error Probability). These HEPs are NOT derived from distributions, but are estimated using techniques like:
   * **THERP (Technique for Human Error Rate Prediction):** As mentioned before, THERP uses a structured process to decompose tasks into smaller elements, assign generic error probabilities, and then adjust them based on PSFs.
   * **HEART (Human Error Assessment and Reduction Technique):** HEART also relies on generic error probabilities associated with different Error Producing Conditions (EPCs) and adjustments for PSFs.
   * **Expert Judgment:** In the absence of sufficient data, eliciting expert judgment is often necessary. This should be done in a structured and defensible way.
   * **Simulation:** Human-in-the-loop simulations can provide data to inform HEP estimates, but they are resource-intensive.
2. **Bayesian Networks:** Bayesian Networks can be used to model the relationships between human actions, PSFs, and system failures. This allows for updating the probabilities of human errors based on observed evidence or changes in the environment. This is an advance approach, but requires detailed data.
3. **Cognitive Reliability and Error Analysis Method (CREAM):** CREAM is a more sophisticated technique that attempts to model the cognitive processes underlying human error.
4. **Qualitative Risk Assessment:** In situations where quantitative data is scarce, qualitative methods such as HAZOP (Hazard and Operability Study) or Failure Modes and Effects Analysis (FMEA) can be used to identify potential human errors and their consequences.

**Why These Approaches Are Preferable:**

* **Focus on Error Mechanisms:** They emphasize understanding the *reasons* why errors occur and the factors that influence them.
* **Flexibility:** They allow for incorporating a wide range of PSFs and dependencies.
* **Transparency:** The methods are generally more transparent than simply fitting a distribution to error data, allowing for easier communication and justification of results.
* **Actionable Insights:** They provide insights that can be used to improve system design, training, and procedures to reduce the likelihood of human error.

**In summary:** Don’t try to force an exponential or Weibull distribution onto human error data. Instead, use established HRA techniques like THERP, HEART, or Bayesian Networks, which are designed to capture the complexities of human performance and the factors that contribute to error. Focus on understanding the error mechanisms and using that understanding to improve system safety.