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FEATURED ARTICLES

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Relationships between Human Factors, Safety Management Systems, and Safety Culture in Maintenance

BY

Dr. Bill Johnson

About the Author: *Dr. William Johnson is the FAA Chief Scientific and Technical Advisor for Human Factors in Aircraft Maintenance Systems. He comments based on nearly 50 years combined experience as pilot/mechanic; professor; engineering airline/MRO consultant, and FAA scientific executive.*

Dr. Johnson discusses maintenance human factors and the critical interaction with Safety Management Systems (SMS) and evolving safety culture. Johnson is positive about increasing workforce recognition and adoption of this important relationship.

I have the opportunity to participate in a number of Inspection Authorization Renewals and airline or maintenance, repair, and overhaul (MRO) meetings. My comments reference the entire maintenance industry from general aviation, to airlines, to military maintenance. I am always impressed with the enthusiasm of the participants with regard to the importance of the application of human factors in maintenance. Sometimes I fear that I am reviewing fundamentals or telling an audience what they already know. However, that does not seem to be the case. Increasingly, there are more questions, more discussions, and more "story-telling."

Maintenance people are familiar with the human factors hazards that permeate the workplace. They have developed a legitimate sense of confidence knowing that their stories are likely more useful than those of the outside human factors expert. I see that situation as an ultimate sign that the maintenance part of this industry has drank some of the "Human Factors Kool-Aid," and they see the value.

Same to You Fella

Maintenance personnel are taking responsibility for attention to human factors. This observation was drilled home to me at a recent airline/MRO meeting. I was telling the roomful of safety professionals, labor leaders, and mid-level managers about how to integrate human factors into their Safety Management System data. At the end of my presentation an articulate labor representative told me that my speech was fine, but I must say more about how to get the message to those working on the shop floor or on the flight line. He was correct. I hope that I answered his valid concerns in a polite and articulate manner. The correct, but overly blunt, answer to his question could have been "That is a very good question but same to you fella." All of us must strive to transmit the HF message to the total workforce, both up and down the worker chain. That includes all level of managers, co-workers, and even FAA Chief Scientists and Aviation Safety Inspectors.

More Than a HF Message

Attention to maintenance human factors is only a part of the overall safe workplace and safe work product. For a long time, the term "Safety Culture" has been floating around safety circles. Definitions are elusive for many. I like to speak these words, never quite the same, that in a safe culture:

- Company leadership communicates and demonstrates that safety is a highest company value.
- Each person in the company adopts that value because they believe it. Each worker is able to clearly articulate what they can do in each of their daily actions to make their contribution to safety.
- Ultimately every manager and worker takes some pride and satisfaction in his or her daily safety contributions.

I would be remiss not to mention that safety is mutually inclusive with efficiency and revenue. Workers must also appreciate that link.

Let the Data Guide You

Relationships Between Human Factors, SMS, and Safety Culture in Maintenance... con't.

How does a worker buy-in and demonstrate his or her commitment to the safety culture? It would be foolish to offer a prioritized list of actions. Having said that, the answer lies in the data. The data, based on industry experience, drives work practices, procedures, and documentation. Therefore, following known valid and reliable procedures ensures safety. Repeatedly, events and accidents are caused by procedural deviation. It is cause #1 of negative events and FAA enforcement against AMTs.

This industry is safe because we are very good about learning from past experiences. Of course, historically that is through reactive data. Something bad happens, so we react and fix the system to prevent that from happening again. The industry will always be reactive to small and large events. That is good.

We have moved past the reactive data and have become more proactive. We conduct safety audits. We chart key performance indicators. We are on the constant quest to ensure that our safety systems work as well as they do. In a safe culture we embrace the audits as an important step towards continuing safety. I am not so naïve to say that we enjoy all audits, but we do understand their value. Audits help ensure order and compliance.

You Guide the Data and You Guide the Procedures/Documentation

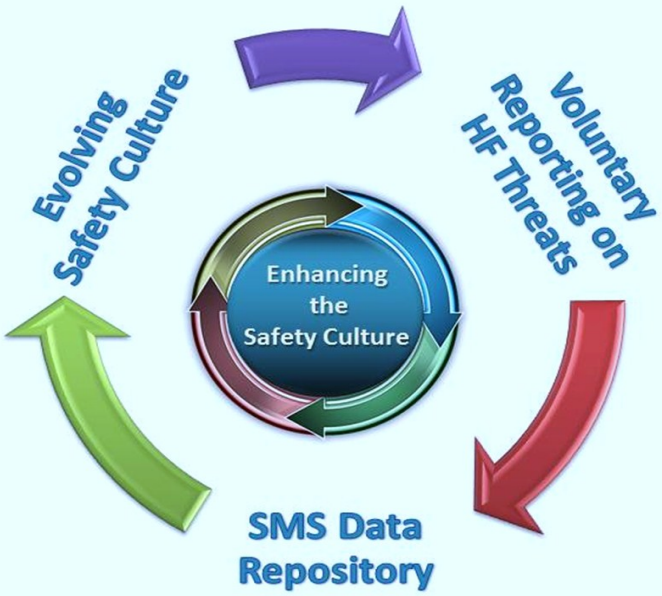
The reactive and proactive data will always contribute to safety, but we can do more when all workers see the value of taking the time to voluntarily report observed threats and errors in their organizations. In today's safe work cultures, the pen, pencil, or keyboard for reporting are as important as any calibrated hand tool. Programs like the Aviation Safety Action Program (ASAP) and the NASA Aviation Safety Reporting System (ASRS) are critical ways to learn about information that otherwise may go unseen in a reactive or proactive data system. The Line Operations Safety Assessment (LOSA) approaches, capitalizing on peer-to-peer observations of normal activities, also has very high potential.

With "failure to follow procedure" being a known major threat, many companies are relying on the new ASAP, ASRS, and LOSA voluntary reports as a way to fix manuals and procedures. In a safe culture, a worker should derive as much satisfaction from completing a voluntary hazard report as completing a task in a phase check. That must be the goal! That way the new procedures are not based on events, but instead, on worker reports that are implemented in a timely manner.

It is a Circle

Worker input on voluntary reporting systems goes far beyond changing documentation. Worker reports on the classic human factors threats are also relevant and important. That includes such topics as:

- fitness for duty,
- communication issues,
- appropriateness of training,
- availability of resources,
- time-pressure, and more.



If this listing is starting to sound like a "human factors lecture" then my mission is accomplished. It reinforces that attention to human factors is integral with SMS, voluntary reporting, and the overall quality of your safety culture.

Protecting YOUR hearing

Part **3** of a **3** part series by **James Allen M.D.**

About the author: *Dr. Allen is a retired navy physician specializing in preventing health effects due to workplace exposure. He is the author of "Working Healthy" and offers the training course ALC-117 on WING to prevent occupational illnesses and injuries. He resides in Wilmington, DE and can be reached either as a FAASTeam representative or through his web site www.workinghealthyalways.com.*

In this final part of the series, we focus on preventing hearing loss. Remember that the first signs of hearing loss are not readily apparent since the frequency lost is above our normal speech frequencies, see part 1. Testing with a hearing booth permits measurements of hearing at specific frequencies including those of normal speech, see part 2. AMTs need no introduction to the importance of prevention. Annual inspections, "C" checks, and preflight inspections are preventive measures that contribute to flight safety.

The concept of preventing hearing loss is simple. Avoid exposure to noise. Implementing this simple concept is quite difficult. In 1903, the Aviation Maintenance, Repair, and Overhaul industry joined other industries where noise is part of the job. The AMT cannot simply walk away from noise and still repair aircraft. So how do you go about preventing noise exposure?

The Safety Hierarchy

The purpose of the Safety Hierarchy (Fig. 1) is to present a hierarchy of preventions applicable to any stressor. Since noise is the stressor of concern, we'll create a hierarchy of controls for hearing conservation. For selecting controls, start at the base.

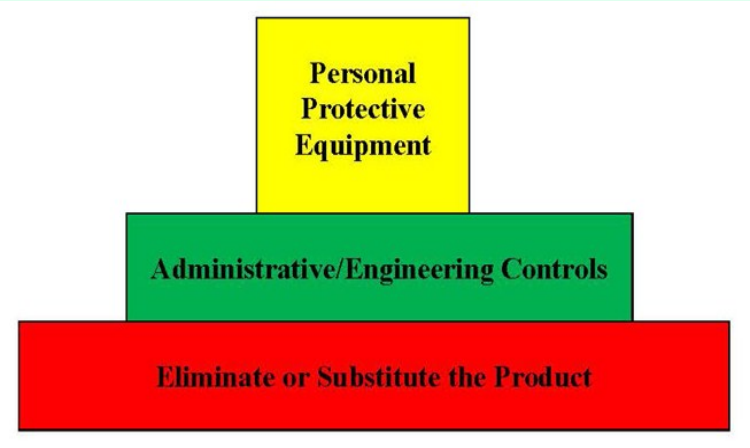


Figure 1: Three levels of the Safety Hierarchy

Eliminating or Substitute the Product

Eliminating or substituting the offending product is the first step in preventing exposures to noise or any stressor. At first glance, eliminating aviation noise means we'd have to eliminate all airplanes with the obvious loss of our jobs as AMTs, but let's think outside the box. For the U.S. and many other countries, the level of noise which requires the employer to provide a hearing conservation program is 90 dB. Audiologists arrived at this standard by assuming an 8 hour exposure to noise at 90 dB with a 16 hour period of rest. In a 24 hour day, the average healthy worker will not suffer a hearing loss with an 8 hour work day exposure at 90 dB(A) followed by rest outside the workplace with no noise exposure.

1 in 5 adolescents (our future AMTs) demonstrates hearing loss

While this model of noise exposure is a nice theory, real world noise exposure is not limited to the workplace. We see AMTs driving away from work with the car radio blasting. Many coworkers carry phones or other devices with ear plugs that funnel sound directly into their ears. Scientific surveys confirm our observations. One in five adolescents demonstrates hearing loss and the prevalence is increasing (Shargorodsky et al., 2010). These adolescents are becoming the new AMTs and are continuing to be plugged into noise. In other words, many AMTs are not resting their ears after a workday exposure to aviation noise.

Protecting Your Hearing...con't.

While we can't eliminate aviation noise, we can reduce noise exposure outside the workplace. After work, the ears should rest. Educate AMTs to turn down their car radios and remove loud ear plugs. Other sensible steps to eliminate noise are to avoid using loud home tools such as a chain saw or drill. Let the ears recover from noise exposure at work by limiting noise exposure outside of work. While recovery time is not exact, a common estimate is "several" hours (Antuñano & Spanyers, 2008).

Administrative/Engineering Controls

An example of the second level of the safety hierarchy, Administrative/Engineering Controls, for AMTs would be the most obvious, Static Engine Runup (SER). This high noise exposure event should not be performed where other mechanics or innocent bystanders are present, as illustrated in figure 2. An administrative policy can dictate that the SER will be performed away from the hangar, preferably behind a concrete barrier or earthen mound.

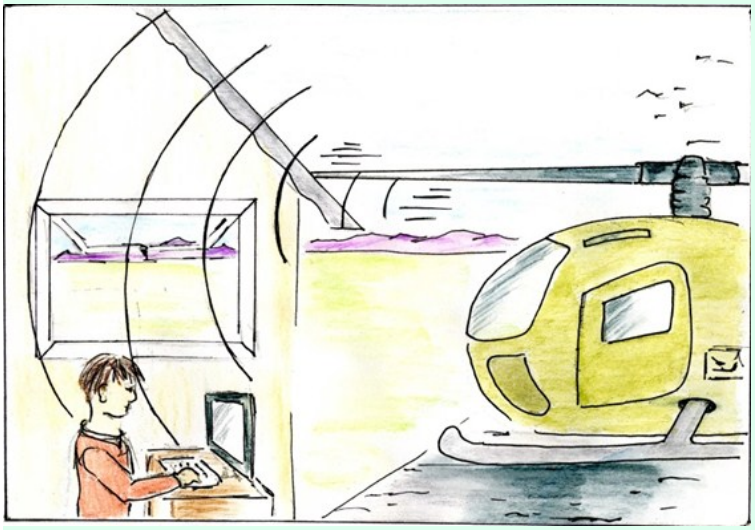


***Figure 2: Innocent Bystander receiving noise exposure during a Static Engine Runup**

Only our imagination limits how we may implement administrative and engineering controls in the hangar. An enclosure around a noisy lathe or grinder is another example of a common engineering control to limit noise. Again, think outside the box. What are you doing that makes unnecessary noise? An often overlooked noise source is poorly maintained hand tools. Fan and ventilators may also deserve attention. A Worker Safety Committee provides a great forum for generating ideas on how to limit exposure to noise or any stressor. Remember, implementing administrative policies or engineering controls is the responsibility of the workplace, not a governmental agency or another company. Implementation of these controls is usually simple and inexpensive, such as changing the location of the SER.

Personal Protective Equipment

Personal Protective Equipment (PPE) is the final level of prevention of the safety hierarchy. Use PPE only when product substitution and administrative/engineering controls fail to prevent or limit exposure to the stressor. Why is PPE the last prevention to implement? The reason is stated in one word…. Fit. If PPE does not fit the user, then the user will not use it.

To illustrate the importance of fit, consider the ubiquitous foam earplug. This PPE can reduce noise presented to the eardrum by about 4 dB. For a 90 dB(A) external exposure the earplug can reduce the exposure at the eardrum to 86 dB(A). To achieve this level of protection the foam earplug must fit into the ear canal. Figure 3, taken from a common supplier of these ear plugs, shows how to correctly insert an earplug.

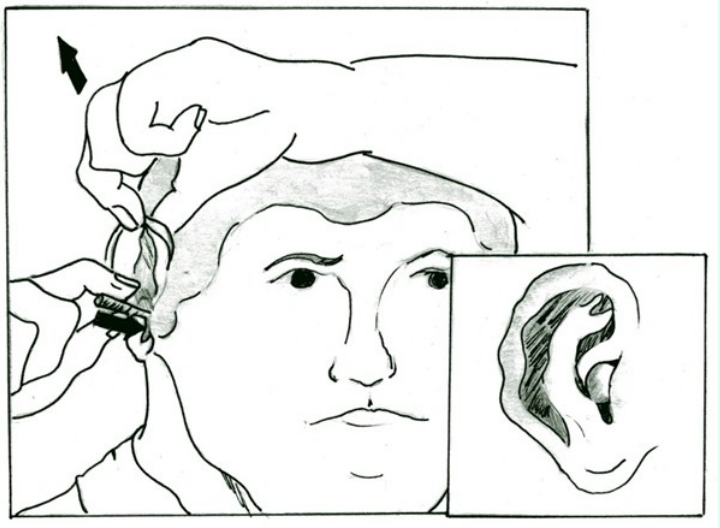


***Figure 3: Correct insertion of the foam earplug.**

Protecting Your Hearing...con't.

To effectively reduce noise, the foam ear plug must expand into the ear canal, not cover it in a wad. To make it fit to your ear canal, first roll it into a small cylinder then insert the cylinder into the canal. As the foam expands it completely seals the canal. A correctly inserted foam earplug has no air spaces to allow the entry of noise. Without appropriate fit, the effectiveness of the earplug is reduced.

The example of the foam earplug is typical of other PPE such as respirators, gloves, and foot protection. Poor fit limits their effectiveness. For the AMT, the goal is to fully use engineering and administrative controls before using PPE.

The Safety Hierarchy is an important concept to consider when preventing workplace exposures that will help protect your hearing.

*Note: All figures are from Dr. Allen's book "Working Healthy, a Manual on Health Techniques for Aviators, Maintainers, and Aircraft Builders" are used with his permission.

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1. Shargorodsky, J, Curhan, SG, Curhan, GC, Eavey, R, "Change in Prevalence of Hearing Loss in US Adolescents" JAMA 2010:304: 772 – 778 also reported in Wall Street Journal, page A5, August 18, 2010
2. Antuñano, M.J., Spanyers, J.P., 2008. Hearing and noise in aviation. Retrieved March 25, 2014 @ https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/hearing. Publication Number:AM-400–98/3.

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The FAA maintenance human factors site was launched in the late nineties. Its popularity grew tremendously over the years. Google hits reached in the hundreds of thousands yearly by 2010. Being over a decade since launched, the website was overdue for a "Heavy Check" to improve its search engine and public accessibility. Fortunately, the "Heavy Check" was not an "out with the old and in with the new." It continues to serve as an important dynamic repository of reports, conference proceedings, and other important MX HF materials. The new HF in Aviation MX website can be found at the original address hfskyway.faa.gov or under a number of alias addresses like humanfactorsinfo.com, and mxfatigue.com. Take a look today and please pass this information to your colleagues.

If you have a story to tell that will help enhance aviation safety, please email katrina.avers@faa.gov or bill-dr.johnson@faa.gov. The editorial staff will help writers with layout and graphics.

If you would like to be added to our quarterly distribution list, please email joy.banks@faa.gov

USING NASA ASRS INFORMATION TO IMPROVE MAINTENANCE SAFETY AND EFFICIENCY

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The National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) database is a public repository serving the Federal Aviation Administration (FAA), NASA, and the aviation industry's collaborative need for effective safety management. It is an important facet of this collaborative effort to maintain, promote, and improve aviation safety. NASA collects aviation safety incident/situation reported voluntarily from frontline aviation personnel. The goal of gathering this information is to enhance human factors research and make recommendations for the improvement of aviation procedures and operations. The information collected in the data base is de-identified for confidentiality and is non-punitive.

We received over 80,000 reports in 2013. Quality reporting at high volume assists valid safety risk assessments. From there, safety assurance and promotion activities follow.

The following ASRS report excerpts were featured in the ASRS monthly safety newsletter, CALLBACK. They present a good overview of the type of information that can be utilized by maintenance organizations to improve maintenance safety and efficiency.

Human Factors in ASRS Maintenance Reporting

Maintenance technicians at many major air carriers routinely receive training to recognize and prevent key human factors that may lead to maintenance errors. The following ASRS report excerpts give first-hand insights into how these factors play a role in maintenance incidents.

Misplaced Tool

Several human factors contributed to misplacement of a jack screw lockout tool used to adjust the horizontal stabilizer jack screw:

- Lack of Awareness: Losing track of tools
- Lack of Teamwork: Lack of mutual support
- Lack of Communication: Failure to discuss job completion

Finalization of all paperwork and work was complete. Close to shift's end, I was called to the supervisor's office. A tool (horizontal stabilizer lockout) I checked out had not been turned in. I asked my partner [who] worked on the project with me if he'd seen the tool. He asked me if I had looked on the shelf behind the jack screw for the tool. I had not. I quickly went to the line to search for the tool, but the aircraft was already gone. We reported the situation to a supervisor who called where the aircraft was headed and left specific instructions. Upon arrival the tool was found. 1) *My partner and I failed to do a tool list check-off. I turned in some tools and he turned in some. 2) The tool room discovered that the tool had not been turned in at shift's end and saw that the others were in. 3) We both had different duties and did not come together at the end to discuss finalization. 4) Upon cleaning the work area…I had no idea that the tool was placed on the shelf behind the jackscrew.*

Rushed for Time!

A B767-300 technician experienced a maintenance discrepancy that is frequently reported to the ASRS:

- Pressure: Rushing to complete the task

Aircraft came in with a pilot write-up, which was also a repeat of nose shimmy on takeoff and wheel retraction. Before the previous flight leg the right nose tire was changed…It came down to replacing

the left nose tire in order to more evenly match-up tire wear and tread. The tire was changed in accordance with the Aircraft Maintenance Manual (AMM). The flight was nearing departure time and obviously rushed, I inadvertently forgot to reinstall the nose tire assembly washer. In [my] years as a certified Airframe and Powerplant mechanic, I've never made such as serious mistake and in the future will slow down so as not to repeat this mistake again.

Failure to Follow Procedures

Maintenance technicians trying to accomplish a strut replacement on a B737-800 failed to follow standard aircraft jacking configuration.

- Lack of Resources: Use of improper equipment

[*We made] a field trip for aircraft strut replacement. We arrived and started inspecting what we had for equipment, tools, and parts. When [we] determined that we were missing a cup for one of the wing jacks, we ordered that and some miscellaneous parts…. We installed the right wing jack and the tail jack in place for stability to remove the #4 brake and #3 tire and brake. We were unable to accomplish this without an axle jack. Instead of waiting for the cup to come, we jacked the right axle with the axle jack enough to remove the bad brakes and tire. When the cup came, we installed it on the left wing jack and placed it in position under the wing. Upon setting that jack in place, we went to check the other jacks to prepare them for jacking and we found that the tail jack had slipped off of the jack pad and punched a hole through the fuselage just forward and outboard of the jack pad.*

When You Assume...

Complacency is a state of self-satisfaction that is often coupled with unawareness of impending trouble.

- Complacency: Failure to verify effectivity

Aircraft 'X' came in with #2 engine, system #1 ignition on MEL. After pushback the #2 engine would not start. We called for the Control Center to order us 2 exciter units, which I installed. The operational check failed. At this point it was the end of our shift. In order to avoid paperwork issues with the next shift, I signed off the log page as replaced units test fails and opened a new log page. Today I found out in (computer system) that the next shift had to replace both exciter units again due to (incorrect) effectivity, which fixed the problem. Next shift found the problem and it was corrected before flight. I should have verified the effectivity, not assume the (controller) ordering the parts would do so.

Triple Fatigue Threat

A trio of human factors led to failure of a B737-300's engine reversers to stow on landing rollout:

- Stress: Rushing to finish jobs
- Fatigue: Not getting enough sleep
- Distraction: Interrupted work assignments

I was assigned 2 aircraft…Working the B737 window heat problem #2 right window, I pulled circuit breakers and 2 boxes, window heat controller [WHC] and the engine accessory unit [EAU] in the electronics bay to gain access to the back side of the WHC bench plugs to do resistance checks, reference maintenance manuals and wiring diagrams. Once I found the problem, I gathered the parts and crimpers I needed. At this time I was told by my lead to drop what I was doing and start working write-ups on a B747. I was told that a widebody had priority over a narrow body. Because I was in the middle of a job on the B737 I finished repairing the broken feed wire to the #2 window, replaced WHC and EAU, and pushed in all breakers. Checked and tested window heat in which the #2 window heat was operating OK. I started working on the B747 until the end of shift. I received a call from the shift supervisor telling me that the B737 landing at another airport had the

reversers deployed but would not stow on rollout. Pilots shut the engines down and were towed to the gate. Maintenance noticed that the EAU was missing. A new EAU was installed and the original EAU was found lying inside [the] E&E compartment on top of the drip curtain above the E&E door opening.

Wrong Interpretation

A B757-200 technician interpreted the stamped numbers on the Auxiliary Power Unit and engine fire bottle squibs as expiration dates.

- *Lack of Knowledge: Lack of training for the task*

…Aircraft was in phase check…I was tasked with checking the APU #1 and #2 engine fire bottle squibs for expiration on their 10-year life cycle. I was not given OJT [On the Job Training] before performing the task. I interpreted parts of the stamped numbers on the shoulder of the squibs to be dates. This aircraft went to heavy check, and it was found that these squibs were near expired or expired…After receiving OJT in reference to the… occurrence, I realized the expiration dates were etched and not stamped on the shoulder of the squibs. I suggested, and my company will modify, their phase task cards to require a date and serial number block be added to the task cards.

Reports like these examples provide direct insights into the daily operational experience of front-line maintenance personnel. Management, FAA, and researchers can use this data to gain a better understanding of the issues facing maintenance personnel and then take action to mitigate the risk of an undesired outcome resulting from these situations.

The ASRS Maintenance Report Form can be filled out and submitted electronically at: http://asrs.arc.nasa.gov/report/electronic.html.

In addition to the reports in the ASRS Database submitted by maintenance personnel, there are also many reports on maintenance issues submitted by flight crews. You can visit the ASRS website and check out the Online Database, the Electronic Report submission portal, and CALLBACK online at: http://asrs.arc.nasa.gov/

C A L L B A C K

ASRS's award winning publication *CALLBACK* is a monthly safety newsletter, which includes de-identified ASRS report excerpts with supporting commentary in a popular "lessons learned" format. In addition, *CALLBACK* may contain features on ASRS research studies and related aviation safety information. Editorial use and reproduction of *CALLBACK* articles is encouraged. Go to: http://asrs.arc.nasa.gov/index.html