Science AMA Series: We're the engineers who saved NASA's planet-hunting Kepler spacecraft, twice! AMA!

Kepler$_{M}ission^{1}andr/ScienceAMAs^{1}$

[1]Affiliation not available

April 17, 2023

the WINNOWER

REDDIT

Science AMA Series: We're the engineers who saved NASA's planet-hunting Kepler spacecraft, twice! AMA!

KEPLER_MISSION R/SCIENCE

[removed]

CORRESPONDENCE:

DATE RECEIVED:
May 05, 2016

DOI:
10.15200/winn.146236.62643

ARCHIVED:
May 04, 2016

CITATION:
Kepler_Mission , r/Science , Science AMA Series: We're the engineers who saved NASA's planet-hunting Kepler spacecraft, twice! AMA!, *The Winnower* 3:e146236.62643 , 2016 , DOI: 10.15200/winn.146236.62643

What caused the "coma" state?

Shaken_U

CS/NASA: Well, it all started with a problem on an internal data bus that got the data traffic out of sync. That resulted in a burst of false fault alarms in a matter of seconds. The onboard computers started to respond to them in a priority order, but the all the responses would take nearly a minute to execute, and before they were done a fault came in that was a top priority, and the spacecraft went to Safe Mode before it finished. That caused the onboard configuration to change, so when the responses completed, they weren't entirely successful. As a result, Safe Mode turned out to be insufficient to and Emergency Mode was invoked 2 hours later. Emergency Mode is what we've called the "coma" state. Emergency Mode is self-sufficient and doesn't depend on the previous state, so when it was invoked, it reset everything it needed and it worked just as designed.

So there are two questions here: What caused the initial problems on the data bus? And why wasn't Safe Mode sufficient?

We don't yet know what caused the initial data problem. We're still investigating, but we may never figure that out.

On the second question, it's beginning to look as though with the several faults that were reported, and the Safe Mode executing in the middle he responses, that onboard heaters were turned off and never turned back on. That could have led to the propellent lines freezing and the the trusters not firing. That then resulted in the spacecraft's attitude slowly drifting until the sun started to peek around the solar panels and Emergence Mode took over.

What caused the "coma" state?

Shaken_U

This is John at Ball - Since Kepler is so far away from Earth it has software onboard to keep it safe when it is not in radio contact with us. This software is continuously monitoring its operation and autonomously places it into a safe state if a problem is detected. The "coma" was triggered when the spacecraft computer detected a number of alarms on an internal communication line. Since the data did not make sense the computer decided to stop its operations and wait for help from Earth.

After we had a chance to review the information stored when the fault occurred, we were able to zero in on the exact time of the error and we saw the errors.

We have not been able to find the exact cause of the original problem (still looking at it) but resetting the various computers ont eh spacecraft has cleared the issue.

First of all great work. I was stupefied to read that Kepler has found over 1000 exoplanets!

What exactly has changed in terms of the data you can collect after the two failures?

[deleted]

Even better: we believe to have foundnearly 5000 exoplanet candidates so far, of which 1044 worlds have been verified carefully using various investigation techniques.

The great news is that the recent emergency mode anomaly hasn't impacted our ability to collect data. We believe it was a "freak", one-off incident from which we have fully recovered. (yay!!)

The loss of the second reaction wheel in 2013 did impact the mission in two ways. First, it put a constraint on where we can point the Kepler telescope. Our trick to use solar pressure to balance the spacecraft only works when we point Kepler towards certain positions in the sky (along the ecliptic plane).

Second, the precision by which we can keep the telescope pointing at a given position in the sky has reduced. Stars now move across our detector by up to 1 to 2 pixels, rather than <0.2 px. This has introduced a small amount of extra noise in the data.

The good news is that astronomers have designed algorithms to remove the extra noise, allowing the current K2 mission to collect data that is almost as good as that from the original mission. Moreover, pointing to new areas in the sky has opened the door to new and exciting science projects.

As a result, we expect Kepler/K2 to continue to yield fascinating exoplanet and science discoveries over the coming months and years!

-- GB (Ames)

How were you chosen as the engineers to save the craft? Was it just you being part of your department or were you selected specifically?

Similarly, were there any internal conflicts on what exactly to do? If so how did you resolve them?

I hope to work at NASA myself someday so thank you for interacting with the public like this! It's great to hear more personally about this sort of work!

TereziBot

This is Colin Peterson from Ball. We engineers, along with the awesome operations team at LASP, are the entire small team that handle the day-to-day operations of Kepler. Therefore, we weren't specifically chosen for responding to the anomalies, it was already our day job (or sometimes night job) to ensure the spacecraft is operating healthy, and doing it's main job of collecting science. When unplanned events happen, such as these rare anomalies, we are ready to respond them quickly, working as a team. Sometimes the way to respond is clear, and we can resolve it quickly using standard procedures already in place. And other times, it is not as straight forward. In these cases, we can call upon other engineers with specific expertise to help troubleshoot and come up with a resolution plan. For this recent anomaly, we were even able to call upon the help from the original

designers of the spacecraft to ensure we could recover safely.

How were you chosen as the engineers to save the craft? Was it just you being part of your department or were you selected specifically?

Similarly, were there any internal conflicts on what exactly to do? If so how did you resolve them?

I hope to work at NASA myself someday so thank you for interacting with the public like this! It's great to hear more personally about this sort of work!

TereziBot

CS/NASA: For the recent Emergency Mode I don't recall a lot of internal conflicts, but we have a policy that we use when dealing with an anomaly. EVERYBODY involved has a metaphorical red-card that they can play if they think we are about to do something foolish. That seldom actually happens, but when is does we slow things down to understand and address the concern.

In this latest instance, there were times when we discussed alternatives, but nothing that resembled a conflict.

How were you chosen as the engineers to save the craft? Was it just you being part of your department or were you selected specifically?

Similarly, were there any internal conflicts on what exactly to do? If so how did you resolve them?

I hope to work at NASA myself someday so thank you for interacting with the public like this! It's great to hear more personally about this sort of work!

TereziBot

This is SWalker from NASA on how are the engineers chosen to save the spacecraft.

There are different elements of the mission that are constantly available to support the spacecraft. There is a mission element that understands the low-level spacecraft components. There is a mission element that communicates with ground stations to and from the spacecraft. There is a project management staff that helps out by ensuring that the overall project goals are still kept in mind.

There are more mission elements for the Kepler mission that are involved in the science, but are not involved in the spacecraft emergency.

So to answer your question specifically, we are staffed all the time to respond to emergencies, and we will then bring on additional specialists to support the recovery.

Having read previous feats of recovering "doomed" equipment via ingenious tricks I always wondered: how do you people try to foster an environment where ideas can be brought forward and examined, despite it seeming to be very outlandish and getting dismissed immediately?

ashemedai

This is John at Ball - When the second reaction wheel failed we were really sad. It looked like the mission was over. But after a few days we decided we gathered up a group of engineering and scientists and started brainstorming. We were very careful to not jump to any conclusions so we could cast our idea net far and wide. This process ultimately yielded both the solution and the new science

program. It took a lot of self control to let the process run its course but it the end the innovation bubbled to the top and off we went with K2.

Having read previous feats of recovering "doomed" equipment via ingenious tricks I always wondered: how do you people try to foster an environment where ideas can be brought forward and examined, despite it seeming to be very outlandish and getting dismissed immediately?

ashemedai

KL - This is a great point. Very simply, it is a choice. We are a fairly small team and no one is smart enough to have all the answers, so any attempt to stifle ideas, however crazy, just does not serve the mission. People are also much happier when they feel they are being heard and have a chance to contribute, and happy people lead directly to a happy spacecraft! If people didn't get behind crazy ideas, Kepler would never have gotten off the ground in the first place.

What do you think is the next stage of exploration for the planets Kepler has found? What observatories might be deployed to study them next?

And thank you for your amazing work, you all are truly inspirational scientists!

Ganesha811

Most of the exoplanets discovered during the Kepler prime mission are too far away to follow up with other NASA missions. However, the exoplanets that are being discovered during the K2 mission using the revitalized Kepler observatory are much closer. Scientists are already using NASA's Hubble and Spitzer Space Telescopes to observe some of those planets and figure out what their atmospheres are like. When the James Webb Space Telescope launches in 2018, we will be able to extend those studies to many more, and even smaller exoplanets (http://jwst.nasa.gov/origins.html). The next mission after JWST will be the Wide Field InfraRed Survey Telescope (WFIRST), and that mission will include and instrument called a coronagraph that can block out the glare of a star and let us observe the (much fainter) planets in orbit around it (http://wfirst.gsfc.nasa.gov/exoplanets.html). Almost certainly WFIRST will observe a bunch of planets discovered first by K2.

What's the hardest thing about managing a spacecraft millions of miles away?

Natsirt2610

Lee/LASP: Wrapping your mind around the two-way light time for real-time commanding. Most of what we do is thoroughly planned in advance, loaded to memory, and then started in the background. But when you're real-time commanding, you have to keep in the mind the sequence of commands, how long they take to function, what the current state of the vehicle is for the command you're sending now, and so forth.

What's the hardest thing about managing a spacecraft millions of miles away?

Natsirt2610

MS/Ames: Another issue with being so far away is that we can't get as much data back as the range to earth increases. That is especially difficult in emergency mode or safemode because we only get data for about 30 minutes every 2 hours. This makes confirming the state of the vehicle difficult. The round

trip light time makes it hard to get the uplink in to the spacecraft to get commands in, and then still confirm that the commands got executed before the spacecraft rotates away. Very slow and painful.

Yours is the most exciting and underrated telescope in operation today. Hubble may provide breathtaking imagery and clues to the formation of solar systems, the early universe, and the chemical composition of the Cosmos (all of which is phenomenal), but Kepler is striding confidently towards that ultimate answer to the first question anyone asks when they consider the stars: are we alone? Fantastic work so far, keep up the magnificent work!

My question:

The K2 mission is enabled by the symmetrical geometry of the spacecraft's Sun shield, allowing it to overcome a reaction wheel failure by *literally balancing on a gods-damn* ***sunbeam***!!!
Was that a design consideration from the start, or a happy accident of geometry that led somebody on the team to have a "EUREKA!" moment?

Destructor1701

This is SWalker at NASA.

Balancing on the solar pressure was not an initial design consideration.

Folks frequently refer to the various engineers working on the Kepler project as 'heroes' or 'geniuses', in the case of K2, some geniuses caucused and came up with a workable solution that provided that EUREKA moment.

While we can't all be geniuses, in this case the folks that came up with the solution were profoundly inspired!

We all owe them thanks!

Yours is the most exciting and underrated telescope in operation today. Hubble may provide breathtaking imagery and clues to the formation of solar systems, the early universe, and the chemical composition of the Cosmos (all of which is phenomenal), but Kepler is striding confidently towards that ultimate answer to the first question anyone asks when they consider the stars: are we alone? Fantastic work so far, keep up the magnificent work!

My question:

The K2 mission is enabled by the symmetrical geometry of the spacecraft's Sun shield, allowing it to overcome a reaction wheel failure by *literally balancing on a gods-damn* ***sunbeam***!!!
Was that a design consideration from the start, or a happy accident of geometry that led somebody on the team to have a "EUREKA!" moment?

Destructor1701

Kipp at Ball - It was definitely not an original design consideration. When we looked at the problem we had, it was simply the answer that presented itself. In these situations you have to work with what you've got rather than what you might like, but we had some really bright people who were able to make it work much better than anyone thought was possible. No one wants things to go wrong, but solving problems like this goes way beyond the usual process of taking years to get it right before a launch and honestly is much more fun. And as a plus we did it within our existing budget, which was FAR cheaper than a new mission. It's really been an honor to be a part of it.

Congrats!

What was the root cause of your most recent anomaly?

Ferret8720

CS/NASA: We don't know the root cause yet. Something caused a problem on the internal data bus (cosmic ray? power fluctuation?). We may never know. But I always start the answer to this question by saying that the ultimate root cause is almost always: "We aren't as smart as we think we are."

Did it involve picking and prodding FORTRAN code?

Also what programming languages are future space programs using ?

ktkps

This is John at Ball -- The Kepler flight software is written in C++. This is also what we are using for future missions at this point. This is mostly driven by our desire to reuse as much code as possible. Spacecraft software must be really reliable and once we get something working and debugged we like to keep using it.

What is the most interesting planet you have found? And what is your day in the job look like? ... thank you for doing this.

theploop

This is SWalker from NASA.

From my perspective, the most 'interesting' planet found as of yet is the planet that orbits two stars. How cool is that!?!

Do you use any off the shelf software to do your modeling work or is everything custom?

bostwickenator

This is John at Ball - We use a mix of custom software, heritage software, and off the shelf software both on the spacecraft and in our ground system. The off the shelf software on the spacecraft is primarily the real-time operating system.

Do you use any off the shelf software to do your modeling work or is everything custom?

bostwickenator

This is Sue from Ball: There are a number of off the shelf software packages used to do modeling. In general these packages assist in custom modeling. The tools vary by subsystem. The Attitude Determination and Control Subsystem, for instance, uses Matlab to do all their custom modeling for the spacecraft dynamics. I know that the thermal engineers and structural engineers do elaborate modeling as well using other tools. Sorry I am not as familiar with those tools.

For the most recent anomaly, can you compare the effect of having a significant light-time delay, while having extended access periods?

I've worked a few anomalies, but they were with satellites in Leo, so we had about nine minutes to communicate with the satellite every 97 minutes.

Can you describe the trade-off between wanting to save propellant and act quickly, versus not wanting to do anything stupid that's permanent and damaging? Would it have even been possible to kill the satellite inadvertently?

Do you think it worked to your benefit that the latest iteration of the guidance and control scheme had just been designed a few years ago, as opposed to the original plan using all four wheels, which I assume went through critical design review around a decade ago?

Did you have the absolute best people in the room? Or were there some folks who, due to the unpredictable schedule of these things happen on, weren't able to contribute the way they would have liked (i.e. Was anybody away on a meditation retreat or on a cruise ship?)

[deleted]

Ball KL - We had 14 minutes two-way light time delay, and the spacecraft was rotating so we lost lock for over an hour at a time followed by 20 minutes of contact. The anomaly caused a lot of havoc and it took awhile to know what the exact telecom configuration was which made things even more challenging. Saving propellant versus acting too quickly was a significant challenge. We don't have much fuel left so an end of mission scenario was very possible. Every day at work is an exercise in risk-benefit trade-offs, so we do have a lot of practice with it. Many choices would normally take much longer to debate and review, but in these situations we often need to rely more on instinct, which can be frustrating and unnerving but it's also why we do what we do. We absolutely had the best people in the room starting at about 6 am after seeing the first signs earlier that night, but schedules can be a challenge sometimes. You have to go with the team you have. Good questions!

What would you like to see in a follow-up to Kepler? And how many of the planets found by either of the Kepler missions can be directly measured by spectroscopy etc?

SpartanJack17

This is John at Ball - Kepler was designed to answer the question of how prevalent are Earth like planets around sun like stars in our galaxy. I think we can safely say Kepler answered this question and really knocked the ball out of the park.

The next questions are what are these planets like? Do they have atmospheres, what chemicals are in their atmospheres, how did they form. These questions are very hard to answer for the Kepler discoveries because many are very far away so they are quite dim. So one logical next step is to look for planets much closer to Earth. This is what NASA's TESS mission will do. And then once we find closer, brighter planets, we need to characterize them with Hubble, the James Webb Space Telescope and the large Earth based telescopes like Keck and Gemini to look for biological signs.

We live in a great time for astronomy. Many of these questions will be answered in our lifetime!

Thank you for everything you do to keep this miraculous program running!

To solve problems like these, it can take considering outrageous ideas on your way to the solution. What were some of the craziest, most "out there", ideas your team considered when facing either of these issues?

dontspeaksoftly

CS/NASA: There certainly was no need for outrageous ideas to recover from Emergency Mode. Though it's a scary place to be, we have procedures for recovering and those procedures worked well. When the second reaction wheel failed, however, we did need to get creative. Before our current solution was worked out, the conventional approach was to point using thrusters only which would have provided minimal science. But I think the other idea that was interesting was to let the spacecraft drift, and take something like a time lapsed image, if we could get it to drift in a repeatable way. Fortunately, we came up with a better approach.

Why is emergency mode on Kepler so fuel intensive?

shuey1

MS/Ames: Emergency mode uses thrusters to keep the solar panels towards the sun but rotate around the sun line so that the communications antennas point to the earth for a while every rotation (about once every 2 hours). Safemode is similar but we have updated the attitude parameters to allow the attitude to be a bit looser, which saves fuel. The emergency mode controller is harder to reprogram, so we have never updated it and it still has tighter controls and hence uses more fuel.

How did you start your career to be what you are now?

kodoku2

Ball -KL One key for me was working in a lab at UNH for many years doing radiation instrumentation development. I had to get a system to work from the detector to the board to the wires and the signal processing boxes all the way to a computer with code running to collect and display the data. Learning how to discern, quickly, that a wire was loose simply by looking at he way the data looked on a plot turned out to be excellent training for flying spacecraft from millions of miles away and debug problems with small amounts of telemetry. You never know what learning experiences from your past will come back to be key, so appreciate them all!

There was a somewhat recent Freakonomics podcast where they interviewed various people that have studied or witnessed major failures (and fear of failure) including the NASA engineer (might have been a contractor to NASA) that initially said they shouldn't launch Challenger due to the O-ring not having been tested at those low temperatures (his manager wound up overriding him and gave the "go ahead"). Does NASA still use those pivotal lessons/events in order to embrace discussions of past and potential failures without fear of management pressure to move forward and stay on time/budget? Or is that a taboo topic that most try not to bring up?

jamkey

This is SWalker from NASA.

That is a great question!

NASA devotes significant resources and effort in retaining lessons learned from previous missions and events, and in fact at the end of each mission, there is a formal step to capture lessons learned from the entire mission's staff.

The NASA lessons learned database is available online, and I would encourage you to search for it. It provides a wealth of information on detailed events and what was learned from those events.

In addition, there is significant oversight from experience experts for all missions. These persons also provide additional insight into 'lessons learned' based upon the unique aspects of each mission.

So this isn't a taboo topic at all.

How long does a signal from Earth take to reach the spacecraft? I hate lag on my computer. I couldn't imagine what it is in space.

Mwaski

Lee/LASP: At the moment of this post, the one way light time to Kepler is 396.614896 seconds. Kepler is in a slightly more elliptical orbit around the Sun than Earth, so the distance changes constantly. Generally it is lagging further and further behind.

More: Two way light time delay is precise, but the processing delays through the ground system add time as well, so even though it looks relatively short, the actual time to command and see it in telemetry can be as much as sixteen minutes or so.

Hey guys, GREAT job. A lot of good insightful questions already, this AMA needs some silliness.

If an Asteroid "Armageddon the movie" sized was found to be headed to our planet in 10 years time how likely is it that you guys could figure out a way to save us all?

Also, small follow up, would sending a bunch of Drilling "Engineers" to space to land on the thing and blow it up be on your top 10 of potential plans?

Thanks again.

wontoomany

It is highly likely - we always make our depth. Sending people would be in my top ten - if I were one of the people!

Hit me with your nerdiest... On a technical level, can you elaborate on your troubleshooting process? how you identified the issue, or how you found a solution?

MDFreaK76

This is Katelynn from Ball. We identified the issue very quickly based on the bit rate that NASA's Deep Space Network acquired the spacecraft at. When we saw in telemetry that we were locked on to the spacecraft at 100 bits per second we knew that we were in Emergency Mode. At that moment, the troubleshooting process started. Every time we acquire the spacecraft, even when we are not in an anomaly, our first order of business is to make sure the spacecraft is safe. Despite being in Emergency Mode unexpectedly, the spacecraft did appear to be fundamentally safe. After health and safety is established, we use existing procedures to elevate the spacecraft to higher and higher states, turning on components and ensuring spacecraft health at every stage. All of the operations entities (NASA, Ball, LASP) were in constant contact to make sure everyone was involved in the troubleshooting process.

Hello, thank you for reading my question.

How long after discovering Tabby Star was it before Kepler went into the "coma state"?

We appreciate everything you do to help us find another home.

Norman_Danks

Kepler observed KIC 8462852 (aka Tabby's Star) during its prime mission, which ran from 2009 through 2013.

The spacecraft is currently carrying out an exciting microlensing experiment as part of its K2 mission!

-- GB (Ames)

What can you tell as about software.Like how its different from regular pc software,what language does it use.How hard is it or how does it feel to be SE working on something so important?

Neca99

This is Sue from Ball: There is a huge amount of software, both flight and ground software, involved in a mission like this for developing the spacecraft, for running the spacecraft and for processing the data from the spacecraft. It is a cornucopia of fun for software engineers. I work primarily with the flight software and some of the ground software used to support and test it. The flight software is written primarily in C++ and the general coding is not so different from the practices of highly reliable ground-based systems. Like most embedded software development, you get to learn a lot about many of the systems that are involved in flying the spacecraft and collecting science data, because ... well ... software controls most everything. The amount rigor in the of development, test and review rigor is quite high. It is VERY cool to work on missions like Kepler and the Hubble Space Telescope. I caught the aerospace bug in college and never left the industry.

Sorry if this has been addressed before, but what caused the reaction wheels to fail in the first place? Is there any chance the problem may have "worked itself out"? Has there been any attempt to restart/restore either of the 2 failed wheels so that the Kepler mission may be extended even further?

MiserableFungi

This is John at Ball - Since we cannot actually inspect the wheel the best we can due is hypothesize about its failure given the data we do have. Based on how it was working during the period before it failed, The problem was most likely a failure of a bearing due to degradation in the lubricant. The wheels are the only moving parts on the spacecraft.

Unfortunately once a bearing has failed there is nothing we can do to repair it. This is where the idea to use photon pressure came in to make up for the damaged wheels and get the science observations back up and running.

We did try and restart one of the wheels and it was clear it was no longer viable.

Did any of you know Dr. David Koch, one of the people behind the Kepler mission, who passed away from ALS recently?

Nukatha

This is John at Ball - Yes many of us worked with Dave on Kepler. He was a brilliant man and directly led to the great success we call Kepler. He was also a joy to work with.

Did any of you know Dr. David Koch, one of the people behind the Kepler mission, who passed away from ALS recently?

Nukatha

MS/Ames Most of us knew Dr. Koch; he was one of the founders of the mission and we still miss his passion for his exoplanet science as well as his terrific enthusiasm for education and public outreach.

What do you think is the most exciting aspect of Kepler's discoveries?

britfaic

This is SWalker of NASA.

I think that the most exciting part of Kepler's discoveries is the childhood wonder that I think we all share in, and that is knowing more about the universe. In particular, who hasn't looked up and wondered about what is out there, and Kepler provides a fundamental step towards answering the question of what is out there.

It is a fascinating question, and each answer to that question is exhilarating!

Did you modify the software so that if this happened again it wouldn't consume fuel in this way?

jdblaich

This is Sue from Ball: No software updates have been required either for reworking the Kepler mission into K2 after the wheel failure or for this latest anomaly. There is a substantial configurability to our flight system. We are looking at updates to some configurations to minimize the fuel impacts of any similar occurrences in the future.

First of all, great job keeping the Kepler program running for so long!

My question; what's your response to the media fantasising about sending humans to closer exoplanets? Is it a load of sensationalism or are there actually observations that look promising?

log-off

First of all, great job keeping the Kepler program running for so long! My question; what's your response to the media fantasising about sending humans to closer exoplanets? Is it a load of sensationalism or are there actually observations that look promising?

FC-NASA HQ: We're not at the point where we can start sending people to exoplanets, but never say never :) TESS will help look for planets that are closer to our solar system after its launch in 2017/2018, and missions like JWST can help better determine what these planets are made of and what's in their atmosphere. Even if we are able to find a promising exoplanet that we'd want to send people to, we'd still need the technology to get there safely. Right now, we're developing the capabilities needed to send humans to an asteroid by 2025 and Mars in the 2030s. For more info, check out https://www.nasa.gov/press-release/nasa-releases-plan-outlining-next-steps-in-the-journey-to-mars/

Is electronics in the spacecraft enclosed within some "life" protection enclosure that maintains temperature and pressure, or is it open to space? How does the choice of components for a spacecraft differ from that for consumer electronics?

DigiMagic

This is John at Ball - The electronics on the spacecraft are packaged in metal boxes that are open to the vacuum of space. We place heaters on and under the boxes to keep the electronics temperatures around room temperature to minimize the stress on the components.

We chose the parts we use very carefully since they operate in a high radiation environment outside the protective cover of our atmosphere. In general the components must be designed from scratch to prevent damage from protons from the sun and cosmic rays from deep space. In Kepler's orbit consumer electronics would not last long enough for us to complete the mission

When did you know you wanted to be engineers?

Eleves_202

This is SWalker at NASA.

I wanted to be an engineer in high school. I liked math and science, and liked things that moved fast...

Aerospace engineer, here I come!

What books are you reading? I am a realistic science fiction fan. Do you have any suggestions for fun reads?

Littleplankton

Kipp at Ball - I'm reading Edgar Mitchell's bio now. I tend towards nonfiction for reading. Sci Fi is my day job :-) Battlestar, Firefly and Interstellar are high on the watching list, though.

How much time did it take the team to get Kepler back up and running, and how does that compare to the time it took to deign/assemble it?

snaerixx

This is Katelynn from Ball. It took about two weeks from when we discovered the spacecraft in Emergency Mode to when we were back successfully collecting science. It was definitely a busy two weeks! The Kepler spacecraft was designed and assembled over several years here at Ball, but part of that pre-launch process is developing procedures to help the future operators when they encounter anomalies.

Unbelievable work with Kepler and everything you guys do at NASA! It's amazing what you all can do.

I know it may not be directly towards the Kepler program in particular, but I've always wanted to ask a NASA scientist about space movies. What do you, as experienced well-educated seasoned engineers specializing in space exploration, think about movies such as Interstellar and The Martian? I just recently saw Interstellar for the third time with my roommates and it caused a spiraling discussion about physics and scientific properties that stumped us in more ways than one. The inner nerd in me

has caused me to have to seen a plethora of space related movies, but I was wondering what you guys think of these more realistic/theoretical movies. Thanks for doing this AMA!

Me_Gusta_Bacon

This is Katelynn from Ball. I actually had seen very few science fiction movies or TV shows prior to starting my Aerospace Engineering education. Once I graduated and started working at Ball, my coworkers were astonished with how few of these "classic" SciFi movies I had seen and created a list of necessary movies. While I still have a ways to go to call myself a SciFi fan, I have seen both Interstellar and the Martian and I enjoyed them both!

How do you deal with stressful situations caused by your work?

FallenAngelChaos

Kipp at Ball - Everyone on the team cares about the spacecraft like it was a part of their family, which can make things stressful when they don't go well. But like with family, if you care about it you find a way to deal with it and turn it into something good. The alternative is not an option.

How do you deal with stressful situations caused by your work?

FallenAngelChaos

This is Katelynn from Ball. Personally, I play ice hockey three times a week as a way to exercise and deal with stress!

What are the capabilities in emergency mode?

Do you have a more manual control of thrusters and sensors so you can try to manually stabilize the satellite?

Or is this only for attempting to fix software problems so that the satellite can be turned back on and fix itself?

dudesec

This is Katelynn at Ball. Emergency mode is the lowest state that the spacecraft operates in, so it is still "on." Emergency mode is designed to be a state that is safe where the satellite can stabilize itself, send a signal to the Earth and wait for the operators (us) to receive that signal and react. When we receive the signal through NASA's Deep Space Network, we can then assess the health of the spacecraft and send commands to bring it to a higher state and turn more components on. This process took two weeks to return all the way to science collection.

What are the capabilities in emergency mode?

Do you have a more manual control of thrusters and sensors so you can try to manually stabilize the satellite?

Or is this only for attempting to fix software problems so that the satellite can be turned back on and fix itself?

dudesec

This is Sue from Ball: Emergency Mode is designed to do exactly what it did. It detected one of several fault conditions that indicated the primary control system was not able to do its job adequately for some reason. It then powers off that control system and takes control itself. The general concept is to use a secondary processor to implement as simple a control system as possible to keep the spacecraft in a safe mode until the ground can intervene and human brains can figure out what to do. It uses a reduced set of sensors and only the thrusters as actuators to control attitude. The thruster control loop is similar to the main control system but reduced to the bare minimum to point the solar array normal at the sun.

How does software and software engineering affect your mission(s)?

Cmac253

Lee/LASP: Software and software engineering is very integral to what we do. Fact is, we're constantly looking for ways to improve the ground software to make it easier to manage the spacecraft. And both students and professionals develop their own software tools for analyzing telemetry and preparing briefings, and some of these ideas are so useful that we put them through a formal process for software release. For the spacecraft, the on-board software goes through intensive development and testing to ensure it is the best it can be before launch. Even so, we always find things on-orbit that could be better and so we make updates to give us better results and longer life.

What's the most seemingly useless skill that you have that somehow applied to your work in saving Kepler?

Also, if you're ever in the area can I buy you a beer?

cjhelms

Kipp at Ball - It may not seem useless, but creativity is perhaps the most underrated skill we use. Without a lot of it to go with the math and physics, we would not be having this discussion today. Also high on the list - humor, good communication, and the ability to go without sleep on occasion. And yes to the beer.