From: "Paul F Austin" <paustin@digital.net>
Newsgroups: sci.military.naval
Subject: Re: Conventional trident warheads
Date: Thu, 3 Dec 1998 08:18:21 -0500

Steve Bartman wrote
>"Paul F Austin" wrote:

>>A 200Kt warhead has a SSKP of virtually 1 for CEPs of 0.2nm or less for all
>>targets (5000psi or less).
>
>What's the hardness of a hardened silo? I don't doubt your formula, I just
>wonder why so much effort went into making the C-4/D-5 better than 0.2nm.

The Hardrock program to increase the hardness of Minuteman silos in the
seventies was shooting for hardness levels over 2000psi but not much harder.
I seem to recall that 4000psi was the upper limit for silos. To exceed those
levels, there was talk of a deep siting system on the south sides of mesas
in the west. The plan was to tunnel into south side (where an ICBM arriving
from Russia couldn't hit) very deeply and have tunneling machinery available
to dig up through the debris. The notions didn't go very far.

The Sovs had (and the Russians still have) some _very_ hard shelters for
command and political cadres that are buried very deep in solid granite. I
speculate that a combination of those, target location uncertainty and the
desire to make the D-5 robust against target hardening played roles in
defining the requirements for Trident.

>>It turns out that if the CEP is on the order
>>500yds, missile reliability is a much stronger driver of SSPK. Historically,
>>ICBMs have managed about 70-80% reliability.
>
>Is that for all nations and both sea and land-based? Sounds low. Maybe
>there's 1950s/1960s data averaged in?

Those numbers were for Minuteman. They would be expected to improve somewhat
with time but the R of a large missile is driven by mechanical components
like motors, nozzles and hydraulics/pneumatics which are much more difficult
to improve by large amounts than are electronics.

...
>First, I clutched on "P-II"--couldn't understand why you were talking
>about Polaris. <g> Second, I can think of lots of reasons P-II might not
>have gone with stellar-inertial. Cost, size-weight (the C-4 package was
>the size of a good suitcase, and the central "ball" the size of a
>volleyball), maintenance needs in the field (FBMs get TLC in their tubes,
>maybe not so in a NATO retreat hauling P-IIs to the rear), size and
>complexity of the targeting computers needed, environmental needs (temp,
>humidity, shocks), others. I don't know anything about P-IIs, but I doubt
>it was a simple technical decision.

All system trades are complex but the P-II guidance set, with a RADAR and
aerodynamic surfaces that had to work at Mach<mumble> were a neat piece of
kit and a very difficult development. The P-II guidance set is no smaller
than the guidance slice for a MMIII (which I know about).

>>>Don't see how "well mapped geodetics" apply in a ballistic weapon. Please
>>>expand? ...
>>
>>One of the significant contributors to the error budget of a ballistic
>>missile (especially an ICBM) is variations in gravitation along the flight
>>path caused by mass concentrations in the Earth.
>
>Didn't know that. Had always heard from the remaining Poseidon types it

>was high-altitude winds. We used to get weather correction messages every
>day on the broadcast. Didn't apply to us, but there were still Poseidon
>boats operatng from Holy Loch in those years.

It's _reentry_ winds that caused dispersion. That's why the thrust of RV design in the seventies was to very high aerodynamic betas (very fine shapes). By not slowing much during reentry, the dispersion due to winds gets smaller. It's analogous to high velocity vs low velocity rifle bullets. As an aside, _pistol_ shooters shoot most accurately with slow bullets since the recoil perturbs the barrel less.

>> A lot of geodetic surveying
>>along likely (read polar) flight paths has been done over the last thirty
>>years by both the US and the exSovs.
>
>But few FBMs would go near the poles. I'm out of my depth talking gravity
>theory though.

Many targets in the ex-Soviet Union were along the north rim of the Arctic Ocean. Virtually all the ICBM tracks were polar and ICBMs faced the hard target problem about 10 years before FBMs did. FBMs sometimes wouldn't fly over the poles. That was one of the attractions of FBMs: it complicated the defense picture. I'm sure that geodetic surveys along other trajectories were done as well.

>As I recall the warhead bus had thrusters to adjust from the stellar fix
>as well as position for RB dumping. Since the stellar fixes are taken
>during the bus phase, at high speed, and the rest of the RB profile is at
>terminal velocity, seems like it would reduce the time available for
>gravity to act, partly mitigating this versus earlier generations.
>Question--what was P-II's maximum altitude? Did it spend more time deeper
>in the gravity well? And what was the source of the comparision for the
>radar-seeker? Seems like you'd need a massive library to cover Eastern
>Europe in 100 yard chunks.

I've never looked at the error budgets quantitatively. If I did, I wouldn't be talking about it here<g>. If Trident busses late (I don't know), that would certainly reduce geodetic errors. It would also simplify the midcourse intercept problem. Most representations of an ICBM mission had bussing occur shortly after second stage burn-out. A minor correction: the RVs travel at the same speed as the bus until reentry. "Terminal velocity" doesn't really apply to an RV since they have such high beta that they're still decellerating on impact. An article in Scientific American (one of Costa Tsipsis' "proofs" that ABMs can't work) had impact velocity for an ICBM on the order of Mach 10.

P-II was a medium range ballistic missile. Reentry velocity and max altitude varies with range. The only references for P-II performance that I had were some pictures of tests at WSMR showing the hole a few feet from the aiming stake. There are a dozen questions that can be raised about that kind of accuracy measurement but P-II was designed to kill the hardest targets.

It wasn't necesary to have RADAR maps of all of Europe. Reconnaisance that identified the target would also have to gather imagery, whether the strike was by missile or aircraft.

>As far as the C-4 CEP, all I can say is we were told different numbers.
>Maybe Lockhhed was doing PR. They did give out nice keychains.

I certainly have only open literature numbers to go by. YMMV. It's been my experience in defense system development on cost contracts that you hit the performance requirements. If you exceed the requirements, you have to justify the costs incurred for "un-needed" performance. Those costs could be non-recurring engineering or recurring costs of a more complex system. Customers (and DCAS) get testy if you spend their money needlessly.

Conscience, that quiet voice that says "Someone may be watching"

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From: "Paul F Austin" <paustin@digital.net>
Newsgroups: sci.military.naval
Subject: Re: Conventional trident warheads
Date: Fri, 4 Dec 1998 21:28:27 -0500

Steve Bartman wrote in message <3666d3e6.3403445@nntp.ix.netcom.com>...
>"Paul F Austin" <paustin@digital.net> wrote:
>
>All very interesting, and, as usual on s.n.n, I learn more than I
>contribute.
>
>>>What's the hardness of a hardened silo? I don't doubt your formula, I
>>>just wonder why so much effort went into making the C-4/D-5 better than
>>>0.2nm.

I'm embarassed to report that I got the relationship between SSPK, hardness,
CEP and yield wrong.
The correct relationship is:
SSPK(Yield_kt, Hardness_Kpsi,
CEP):=1-0.5^(8.41*(Yield/1000)^(2/3)/(Hardness^0.7*CEP^2))
The probability of kill is a lot lower than I originally calculated (damn
spreadsheets) because I was dividing Hardness by 1000 originally.

Against a 1000psi target, here are the SSPKs for several yields and a couple
of CEPs:

CEP	Y(kt)	SSPK
0.1	100	63%
0.1	200	79%
0.1	500	95%
0.2	500	51%
0.2	1000	69%

I've capture these relationship in a spreadsheet that lets you enter ranges
of CEP, Hardness, Yield and gives you SSPK. It also, given Pk required and
reliability, gives you the number of shots required. Anyone interested can
have a copy by E-mailing a request to me.

>>The Hardrock program to increase the hardness of Minuteman silos in the
>>seventies was shooting for hardness levels over 2000psi but not much
>>harder. I seem to recall that 4000psi was the upper limit for silos.
>
>Okay. I had absolutely no feel for even a range here. Still, 4000 psi
>seems low, given you're on land, steel and concrete are cheap, and the
>thing never has to move anywhere. Also, given the national imprtance of
>the missiles' survival. Perhaps just easier to go for quantity over
>quality and count on better C&C, and a unified NCA, to get some of them
>away before a first strike took them out.

This isn't something I'm expert in so take this as the speculation it is:
To build an extended structure that can withstand overpressures in the
5000psi and up range requires that you can carry the loads downward and
spread them out till the base material you're building on doesn't collapse.

Consider a 30 foot wide circular structure, at 5000psi that results in a
load of 254,000 tons. If the load is carried by a 10% thick cylindrical

support (3 feet wide), the load is 12,500psi (if I did my sums right). That seems like a lot to me but I'm no civil engineer and have no idea what a reinforced concrete structure can bear in compression.

As I recall, only sites with granite foundation to build on were suitable for the Hardrock program. A significant difficulty in designing supremely hard silos was to keep the missile from rattling against the sides of the silo. That makes the tube in the silo bigger as a function of overpressure (seems linear). As the tube gets bigger, the forces transmitted go up as a square function of diameter so that the forces that the silo structure have to deal with are a cube function of the overpressure that you're trying to withstand.

There are also limits to the overpressure-hardness-SSPK relation because if the silo gets into the fireball proper, it's going to be volatilized. That's the motivation behind the deep siting options. If you get your missiles deep enough, even if the warhead detonates right over your position, the crater depth is less than the depth of the hole you're in. This was the basis for an apocalysm novel called "Level-7".

...
>>I've never looked at the error budgets quantitatively. If I did, I
>>wouldn't be talking about it here<g>. If Trident busses late (I don't
>>know), that would certainly reduce geodetic errors. It would also
>>simplify the midcourse intercept problem. Most representations of an
>>ICBM mission had bussing occur shortly after second stage burn-out.
>
>Not sure what you specifically mean by "bussing." Discarding the shroud?
>Initial RB dump off? Disconect from second stage? I'm going off general
>lectures, but it was emphasized that the bus could maneuver for specific
>RB insertion to form the footprint. Beyond that I'm not much help.

In the ballistic missile business, "bussing" is the term used for the bus's manuevers that result in launching of each RV. The MIRV bus manuevers to give crossrange velocity and adjust downrange velocity till the whole assemblage traveling toward the next target, then releases an RV. The bus then manuevers till it's traveling toward the next target and releases the next RV and so on.

>> A minor correction: the RVs travel at
>>the same speed as the bus until reentry.
>
>That makes sense if they're still connected. My memory of the C-4 system
>was not a "formation flight" of the bus and detatched RBs, but rather a
>rapid angle/velocity separation after RB release with the warhead
>starting down immediately. A sequential dump IOW. Depending on footprint
>shape there could be very rapid RB releases, or more leisurely
>performance by the bus.

The RVs travel with the velocity vector that the bus had when they're released. The velocity vector will differ for each target and the RVs will disperse from each other and from the bus. The scalar difference in velocities among the RVs is small compared to the general downrange velocity. I've no idea (and suspect it's highly classified) what the maximum difference in velocities would be. Since the bus has a fairly small delta-V budget compared to the booster, the scalar differences will be fairly small. The distance between RVs has the remainder of the flight to build up based on the divergent velocity vectors.

>> An article in Scientific American (one of Costa
>>Tsipsis' "proofs" that ABMs can't work) had impact velocity for an ICBM on
>>the order of Mach 10.
>
>That would be roughly 8000MPH? Hmm. Again, I remember higher numbers from
>Kwajelein tests, in the low five figures. Long time ago now, however.

Three conditions may apply: I remember wrong, SI got it wrong or it may have been in the early seventies and reentry velocities may have been lower. I have no direct knowledge one way or the other. I _do_ remember vividly the described effect if the RV hit a speck of sand thrown up by an earlier detonation at those speeds. It made Richard Garwin's suggestion of using small nuclear weapons detonated near the silos as a method of defense make sense. _Insane_ sense, but sense.

>>It wasn't necesary to have RADAR maps of all of Europe. Reconnaisance
>>that identified the target would also have to gather imagery, whether
>>the strike was by missile or aircraft.
>
>I wonder, in a full-scale European war, how reasonable that assumption
>would have been, especially if the Soviets had gone nuclear first and
>with the chaos that would have caused in the West's C&C.

As I understood it, one of Pershing-IIs missions was to kill time-urgent mobile targets in a nuclear environment. That implies a robust system of reconaisance assets. God help the RF-4 pilots under those circumstance.

...>>I certainly have only open literature numbers to go by. YMMV. It's been my
>>experience in defense system development on cost contracts that you hit
>>the performance requirements. If you exceed the requirements, you have
>>to justify the costs incurred for "un-needed" performance. Those costs
>>could be non-recurring engineering or recurring costs of a more complex
>>system. Customers (and DCAS) get testy if you spend their money
>>needlessly.
>
>Again, no data at all to work with on this specific issue, but I wonder
>if any excess performance in Trident could have been a function of gear
>Lockheed didn't work on, specifically the Nav Center improvements
>(Sperry) that came in after the Trident program was well underway. You'd
>think that they'd talk during development and share, but who knows. Above
>my paygrade.

One thing that comes to mind: the performance spec are worst case ones. Most actual components are very near nominal so most systems will perform nearer "best case" rather than "worst case".

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