SCEC Committee for Utilization of Ground Motion Simulations Meeting 4

Organizers: C.B. Crouse (URS) and Tom Jordan (SCEC/USC)
Date: Monday, May 4, 2015 (10:00-15:30)
Location: SCEC Media Room (ZHS 165), USC, Los Angeles, CA

Agenda

10:00	Welcome and introductions	
10:15	Introductory Remarks and Meeting Agenda	C.B. Crouse
10:30	New Code Cycle (Project 17, BSSC Issue Teams, ASCE 7 SSC)	C.B. Crouse
10:45	Update on SCEC CyberShake Progress	Tom Jordan / Phil Maechling
11:30	Calculation of Risk-Targeted Maximum Considered Earthquake Response Spectra (MCER)	Scott Callaghan
12:00	Lunch	
13:00	Southern California MCER Sa(T) maps – CyberShake vs. 2013 NGA West2 - CyberShake & NGA West2 Sa maps for T = 3, 5, & 10 sec - Ratio Maps (CyberShake/NGA West2) for each T - Discussion	Kevin Milner
13:30	Calculation of v15.4 Risk-Targeted Maximum Considered Earthquake Response Spectra (MCER) at 14 Southern California Sites (T = 2 – 10 sec)	Scott Callaghan
14:00	Effect of Near-Surface Geology - SCEC Thick Surface Layer with Constant Material Properties vs. Realistic Model with Depth-Dependent Material Properties - Results of 1-D Site Response with Both Models - Discussion	C.B. Crouse
14:30	Break	
14:45	Technical Issues, Logistics, & Schedule for Producing Long Period MCER Maps for L.A. Region in Short Term (e.g., Possible supplement to ASCE 7-16 for City of L.A.) and Long Term (2021 NEHRP & 2022 ASCE 7)	C.B. Crouse
15:00	Future Work for CyberShake	Tom Jordan
15:15	Results to be Presented and Tentative Dates for Next UGMS Meeting	
15:30	Adjourn	

Participants

Member Attendees (*in person*)	Member Attendees (*remotely*)	Members Absent	Observers
C.B. Crouse - chair	Jack Baker	Norm Abrahamson	Brad Aagaard
John Anderson	Jacobo Bielak	Bob Bachman	Domniki Asimaki
Rob Graves	Art Frankel	Ron Hamburger	Nenad Bijelic
John Hooper		Curt Haselton	Scott Callaghan
Marty Hudson		Lew Marshall	Tran Huynh
Tom Jordan		Farzad Naeim	Ting Lin
Charlie Kircher		Paul Somerville	Phil Maechling
Nico Luco			Kevin Milner
			Morgan Moschetti
			Kim Olsen
			Sanaz Rezaeian
			Andreas Skarlatoudis
			Ricardo Taborda

Report of the SCEC Utilization of Ground Motion Simulations (UGMS) Committee Accomplishments during 2014

By: C.B. Crouse and T.H. Jordan

Introduction

The goal of the UGMS committee, since its inception in the spring of 2013, has been to develop long-period response spectral acceleration maps for the Los Angeles region for inclusion in NEHRP and ASCE 7 Seismic Provisions and in Los Angeles City Building Code. The maps are to be based on 3-D numerical ground-motion simulations, and ground motions computed using latest empirical ground-motion prediction equations from the PEER NGA project. The work of the UGMS committe is being coordinated with (1) the SCEC Ground Motion Simulation Validation Technical Activity Group (GMSV-TAG), (2) other SCEC projects, such as CyberShake and UCERF, and (3) the USGS national seismic hazard mapping project. Significant progress toward developing the maps was made in 2014, and this summary report highlights the accomplishments and future work.

Background and Motivation for Long Period Ground Motion Maps

Section 11.4 in the current ASCE 7-10 (and forthcoming ASCE 7-16) standard specifies a general procedure for developing risk targeted Maximum Considered Earthquake (MCE_R) response spectral accelerations at intermediate and long periods. These long period accelerations depend on two parameters, S_{M1} and T_L, where S_{M1} is the MCE_R response spectral acceleration at 1-sec period that accounts for the effect of the local site geology through the site coefficient, F_v, and T_L is the period that defines the transition in the MCE_R spectrum from constant spectral velocity to constant spectral displacement.

The T_L parameter was introduced in the ASCE 7-05 standard to provide a more realistic estimate of the response spectrum at long periods. The values of T_L vary from 4 sec to 16 sec depending on location in the US. During its development, deficiencies in the T_L concept were recognized, but a better representation of the long period motions was not possible at the time because the existing ground motion prediction equations (GMPEs) did not extend to long periods.

The subsequent NGA West and NGA West2 projects, culminating in 2008 and 2013, produced GMPEs for computing response spectra to 10-sec period from shallow crustal earthquakes in the western US. Although these GMPEs were derived from an extensive world-wide ground-motion database, relatively few truly strong ground motion records in this database were from earthquakes in the Los Angeles area, where the effects of the complex 3-D basin structures were known to have significant influences on long period motions. Furthermore, the earthquakes on the local faults contributing to the MCE_R motions in Los Angeles have not occurred during the last several decades when the region was populated with arrays of strong motion instruments.

The available ground motion data for southern California did suggest a correlation between long period ground motions and basin depth. Thus, NGA West, NGA West2, and a few previous generation GMPEs incorporated a basin depth term to model the effect of the basins. However, this parameterization ignores the 3-D effect, as well as the location and orientation of the fault rupture with respect to the basins. Recognizing this deficiency in the empirical GMPEs, SCEC launched a program to simulate ground motions numerically using a physics-based 3-D fault-rupture and wave-propagation model of Southern California. The computations were done with the CyberShake platform that utilized supercomputers to generate millions of simulations covering the range of potential moderate to large magnitude earthquakes on Southern California faults included in the Uniform California Earthquake Rupture Forecast (UCERF) models the USGS has used to develop the MCER ground-motion maps for the region.

The potential feasibility of using CyberShake to develop long period ground motion maps was demonstrated by SCEC (Graves et al., 2010; Wang and Jordan, 2014), and this eventually led to the formation of the SCEC UGMS committee.

Results Generated by UGMS during 2014

During its May 2014 meeting, the UGMS committee decided to conduct further tests of the feasibility of CyberShake at 14 sites in Southern California (Figure 1). These sites were selected to capture a representative range of different effects (i.e., deep basin, basin edge, directivity, near field). MCE_R response spectra were computed at these sites using the CyberShake simulations and the NGA West and NGA West2 GMPEs. (The Idriss GMPE was not used because it did not account explicitly for basin effects.) The NGA GMPEs required estimates of the Vs30, the average shear-wave velocity in the upper 30m, and the basin depth term, $Z_{1.0}$ or $Z_{2.5}$, the depth to the top of the layer with a shear-wave velocity of 1 km/sec or 2.5 km/sec, respectively. Values estimated for these parameters at the 14 sites are listed in Figure 1.

SCEC developed a web page containing the results of the MCE_R calculations, which involved computing the following at each site:

1. The 5% damped, horizontal component, response spectra in the direction of maximum shaking.

2. Probabilistic MCE_R at each site, which required the convolution with a generic fragility function, per Section. 21.2.1.2 of the ASCE 7-10 standard.

3. Deterministic MCE_R, including the Deterministic Lower Limit MCE_R, per Section 21.2.2.

4. MCE_R response spectrum as the minimum of the Deterministic and Probabilistic MCE_R, per Section 21.2.3.

The CyberShake-based and NGA-based MCE_R response spectra were computed at common periods of 2, 3, 4, 7.5, and 10 sec; the NGA-based spectra were also computed at 1 and 1.5 sec periods. After observing the results, it was quickly recognized that CyberShake underestimated the response spectra at 2-sec period (see Wang and Jordan, 2014, Fig. 6), a limitation that will be corrected in 2015.

The results of each step above were archived in various links in the SCEC web site, CyberShake MCE_R, at http://scec.usc.edu/scecpedia/CyerShake_MCER. The MCE_R response spectra from Step 4 were plotted on log-log graphs with the vertical axis being 5% damped, horizontal component, pseudovelocity [PSV = $(T/2\pi)\ S_a$, where S_a is the response spectral acceleration], and the horizontal axis being period, which ranged from 1 to 10 sec. Each plot presents the results for one of the 14 sites, and it compares the MCE_R response spectra from the CyberShake simulations, the 2013 NGA West2 GMPEs, and from the General Procedure of Section 11.4 of ASCE 7-10. The plots follow Figure 1, and the abbreviation at the top of each plot identifies the site in the figure.

Several observations are apparent from the MCE_R response spectra plots:

1. As noted above, the CyberShake spectral ordinate at 2-sec period was underestimated, and the amount of the underestimation was a factor of ~2.

2. The CyberShake-based and NGA West2 GMPE-based MCE_R response spectra were within a factor of 2 of each other in the 3 to 10-sec period band, and for some sites the two spectra were virtually identical.

3. An average of the CyberShake and GMPE-based MCE_R response spectra from 3 to 10 sec provided a curve that was a fairly smooth transition to the GMPE-based MCE_R response spectrum between 1 and 3 sec.

Conclusions

The results generated during 2014 are encouraging and indicate that the UGMS committee should continue its efforts toward generating long period ground motion maps for Southern California for possible inclusion in (1) the next edition of the Los Angeles City building code, which would be a variation to the ground motions for Southern California in the ASCE 7-16 standard, and (2) the 2020 NEHRP seismic provisions and the ASCE 7-22 standard. The code cycle for the latter has already begun.

A few technical issues will need to be addressed before draft maps can be prepared. One item was the placement of the hypocenter at the bottom of the thrust/reverse faults in the CyberSkake rupture realizations, which would tend to introduce more directivity from upward propagating ruptures than was considered realistic. It was agreed that a more more uniform distribution of hypocenters with depth for these faults should be made for future CyberShake runs.

Another issue was the effect of the near surface velocity model on the ground motions CyberShake generates at shorter periods ~ 2 sec. The sensitivity of ground motions will be checked at a few basin sites resulting from (1) a finer mesh of the near surface geology over a depth ~200m, and (2) a more realistic velocity structure over this depth. Depending on the results, some refinements may be made.

The UGMS committee must also decide how to include the CyberShake simulations in the preparation of the ground-motion maps. The MCE_R response spectra at the 14 sites indicates both the 2013NGA West2 GMPEs and the CyberShake simulations should be used, but the exact procedure will probably be determined toward the end of 2015.

References

Graves, R. and 12 coauthors, 2010, CyberShake: a physics-based seismic hazard model for Southern California. Pure Appl. Geophys., DOI:10.1007/s00024-010-0161-6.

Wang, F., and T. H. Jordan (2014), Comparison of probabilistic seismic hazard models using averaging-based factorization, *Bull. Seismol. Soc. Am.*, **104**, 1230-1257, DOI:10.1785/0120130263.

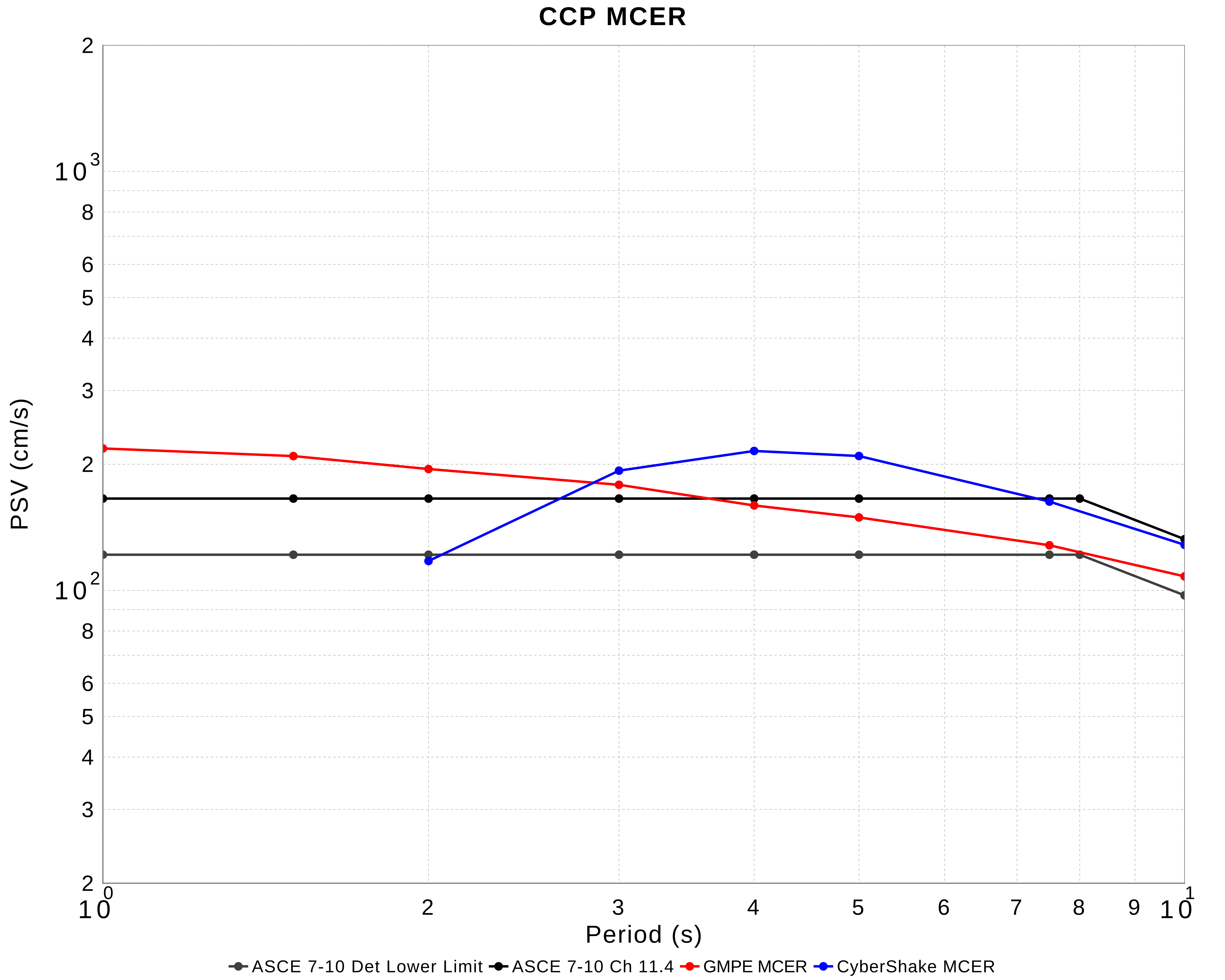
Acknowledgements

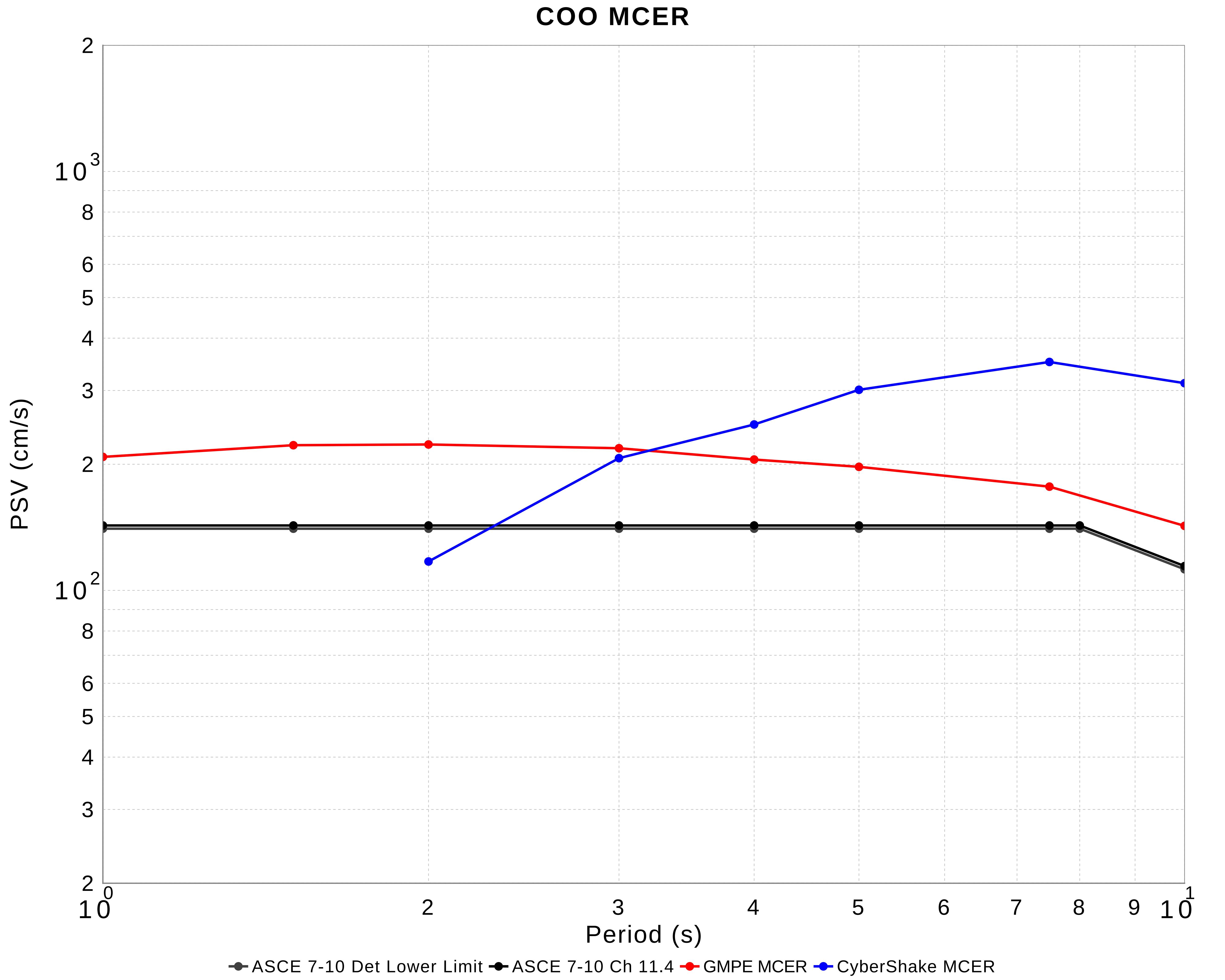
The work done by Scott Callaghan, Kevin Milner, and Philip Maechling of SCEC to compute the MCE_R response spectra and prepare the CyberShake MCER web site with these and other data related to the calculations, is greatly appreciated, as well as the contributions of the UGMS committee members and corresponding members.

Figure 1
Locations of 14 Sites and Their Vs30, Z1.0, Z2.5 Values

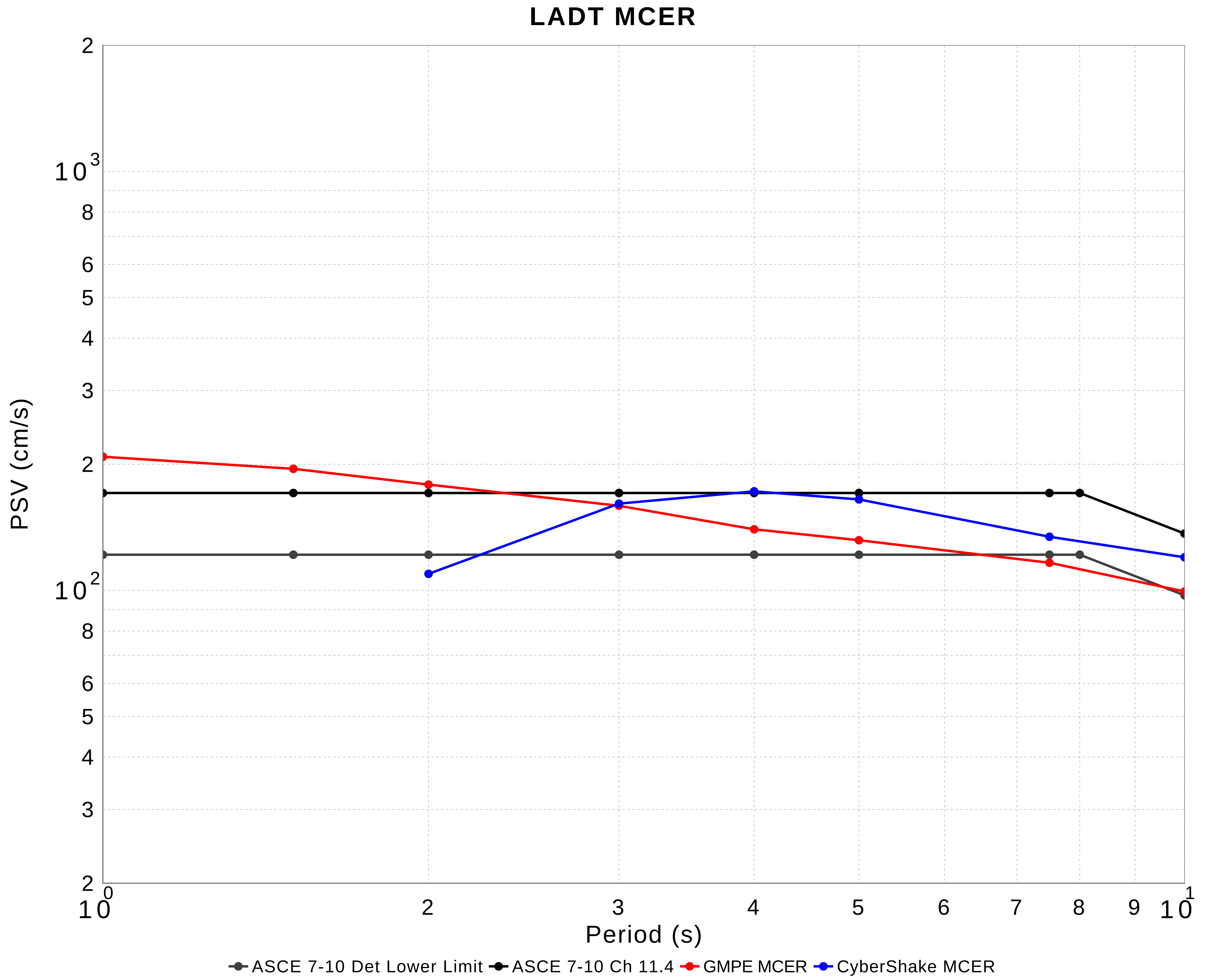
Site	Latitude	Longitude	Vs30 (Wills 2006)	Z1.0 (CVM-S4.26)	Z2.5 (CVM-S4.26)
CCP	34.05489	-118.41302	387	0.39	2.96
COO	33.89604	-118.21639	280	0.73	4.28
LADT	34.05204	-118.25713	390	0.31	2.08
LAPD	34.55700	-118.12500	515	0*	0*
P22	34.18277	-118.56609	280	0.22	2.27
PAS	34.14843	-118.17119	748	0.01	0.31
s429	33.80858	-118.23333	280	0.71	2.83
s603	34.10275	-117.53735	354	0.19	0.43
s684	33.93515	-117.40266	387	0.15	0.31
s758	33.37562	-117.53532	390	0*	1.19
SBSM	34.06499	-117.29201	280	0.33	1.77
SMCA	34.00909	-118.48939	387	0.59	2.47
STNI	33.93088	-118.17881	280	0.88	5.57
WNGC	34.04182	-118.06530	280	0.51	2.44

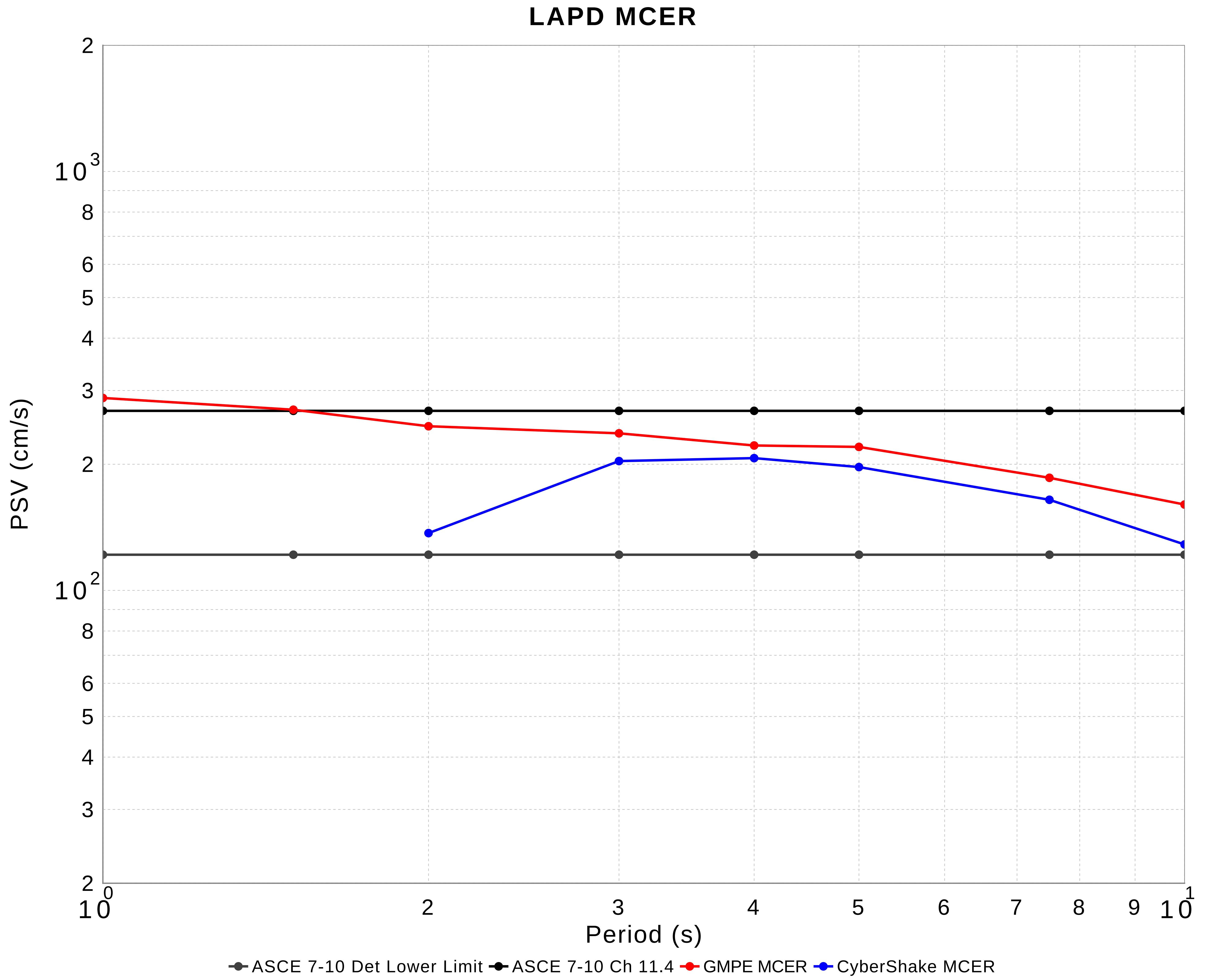
*CVM-S4.26 has a Vs30 larger than the Z-value, so the depth is essentially 0.


CCP MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER

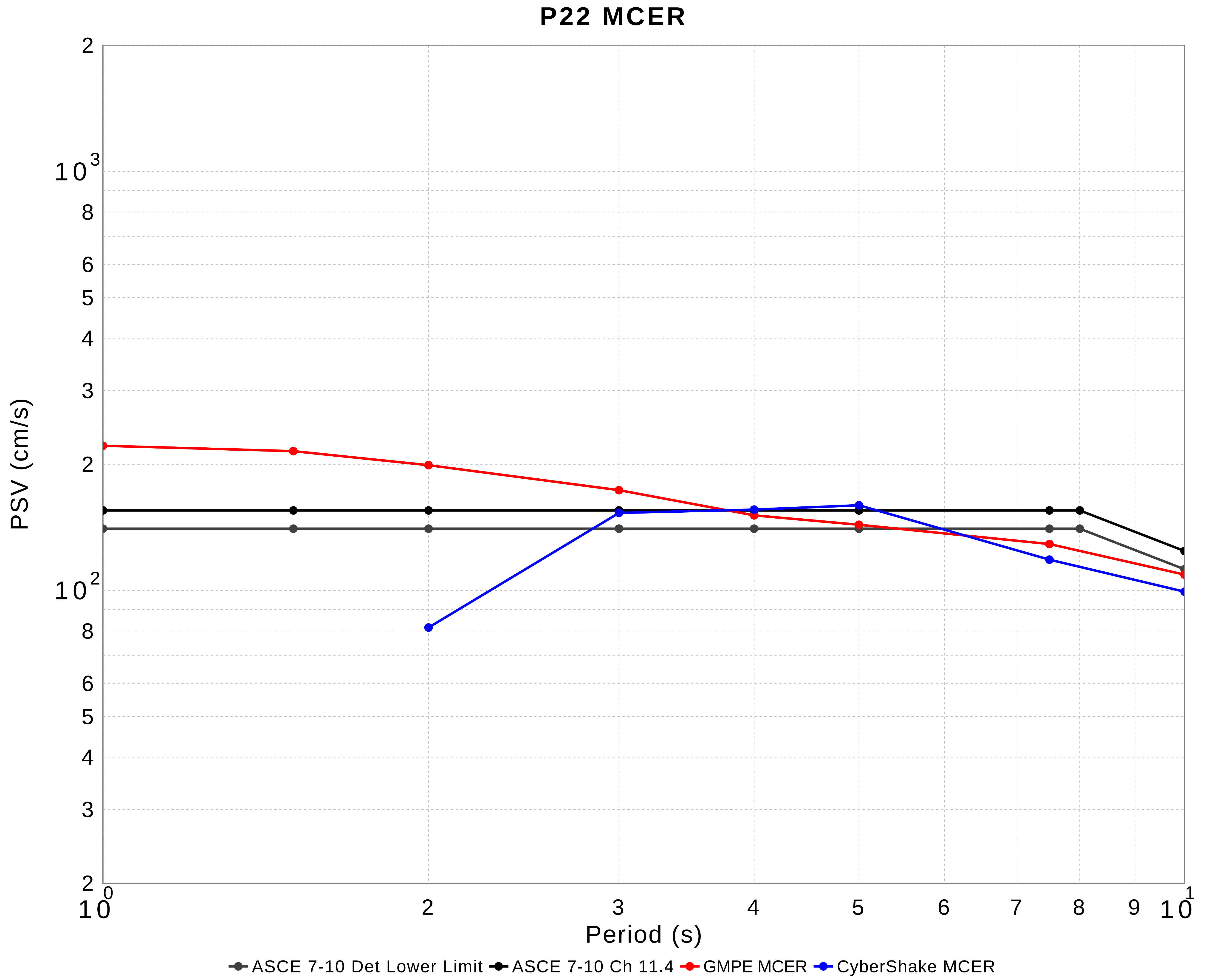


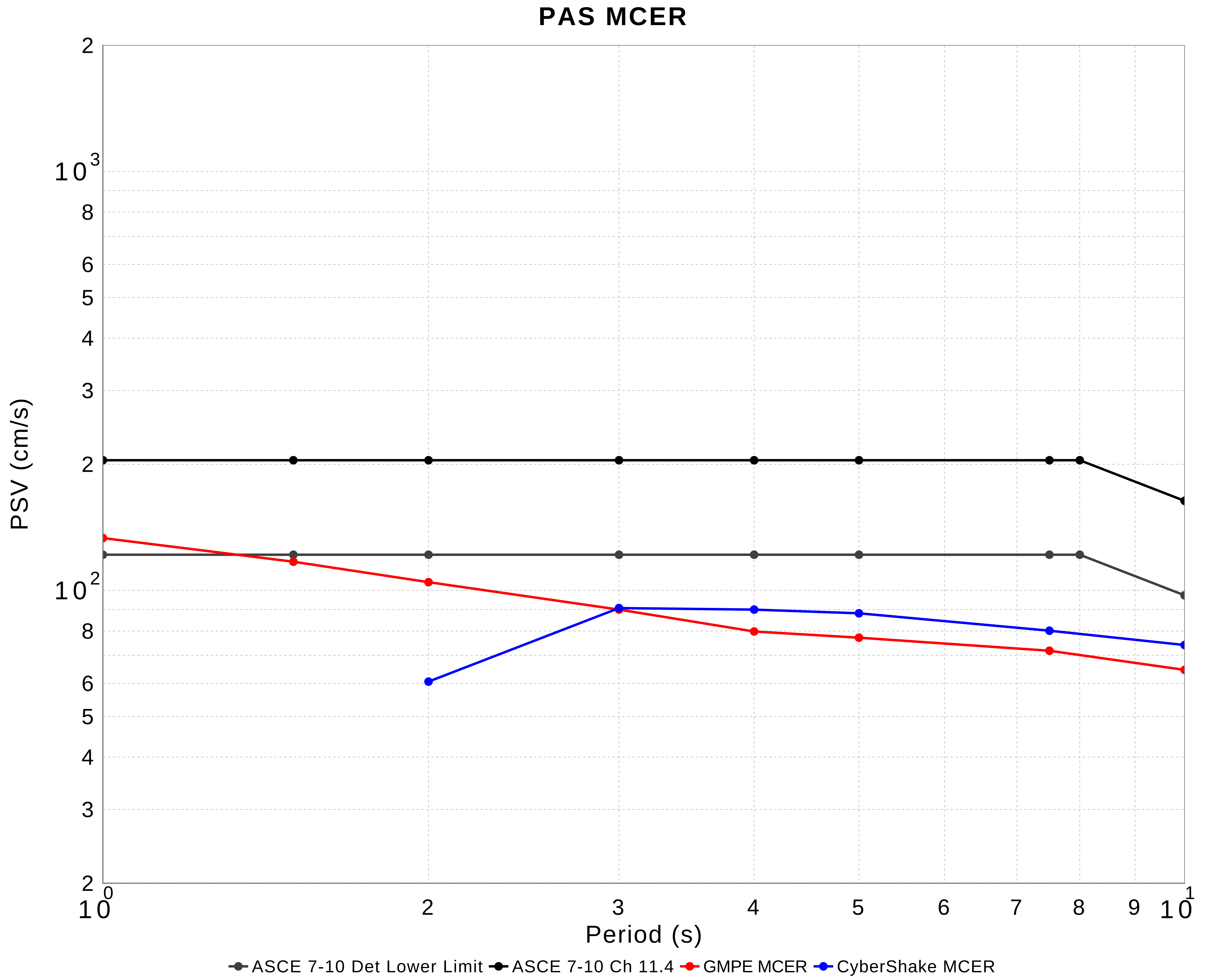
COO MCER
PSV (cm/s)
Period (s)
2
10^3
8
6
5
4
3
2
10^2
8
6
5
4
3
2
10^0
2
3
4
5
6
7
8
9
10^1
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER

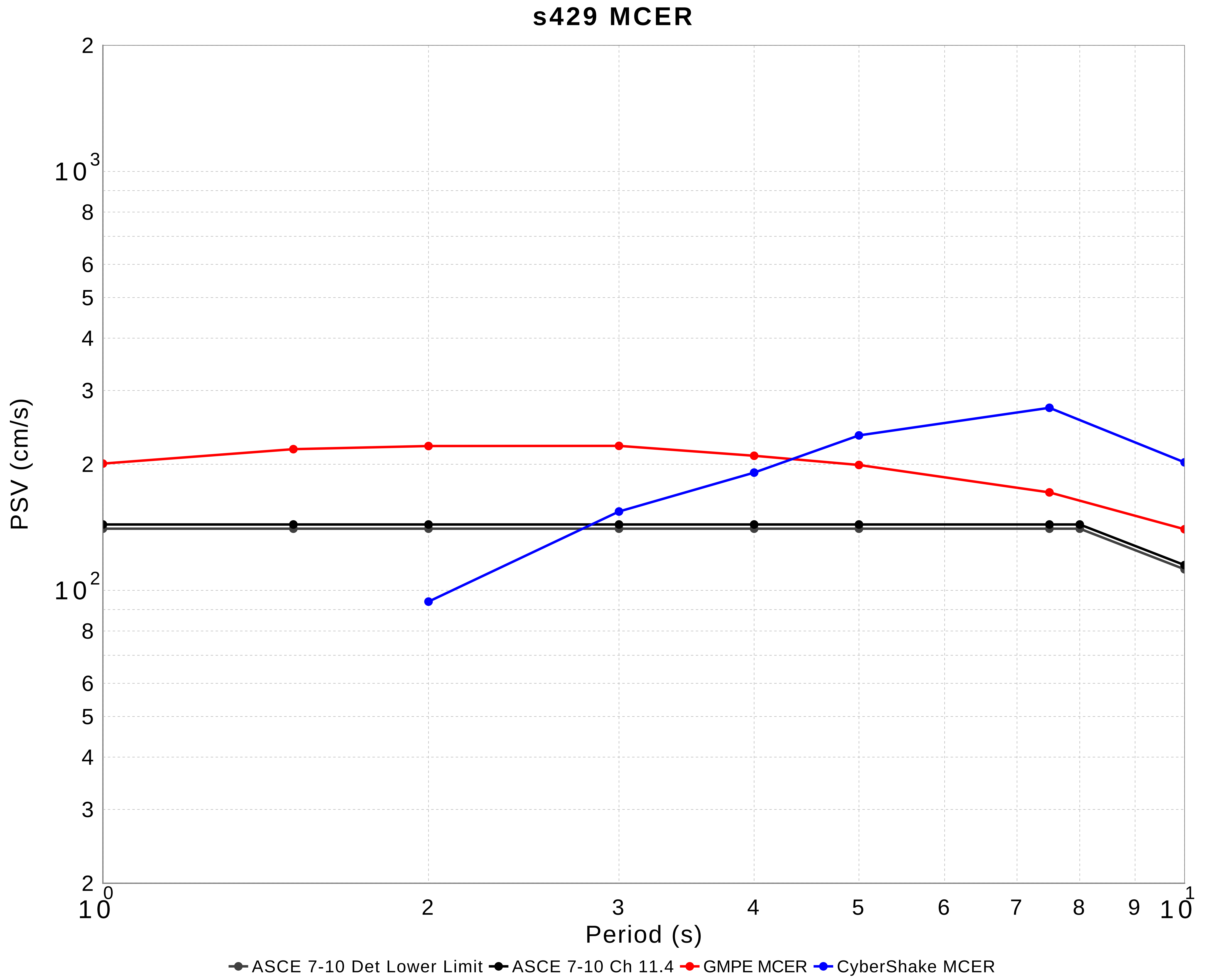

LADT MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER



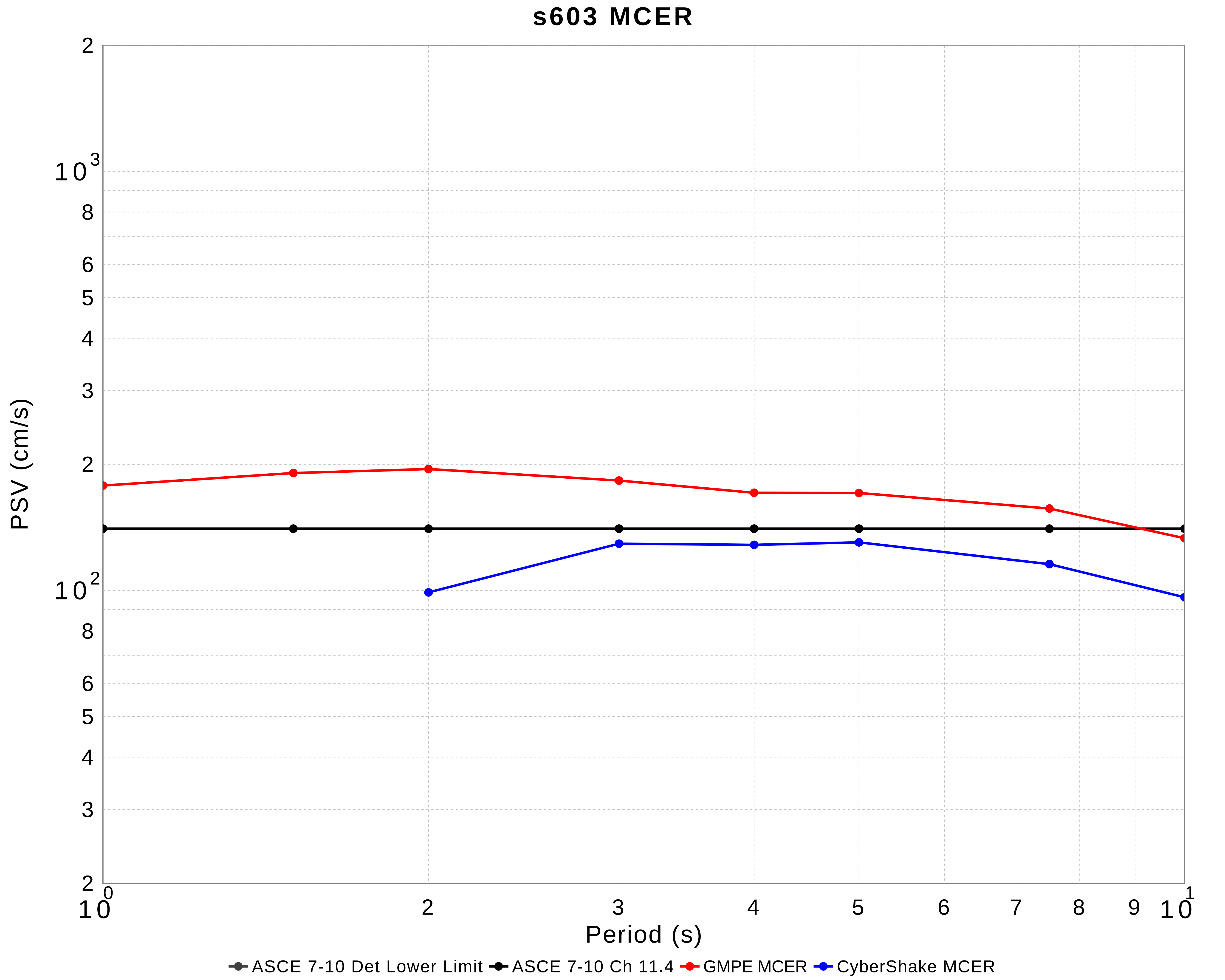
LAPD MCER
PSV (cm/s)
Period (s)
10^3
10^2
10^0
10^1
2
3
4
5
6
7
8
9
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER

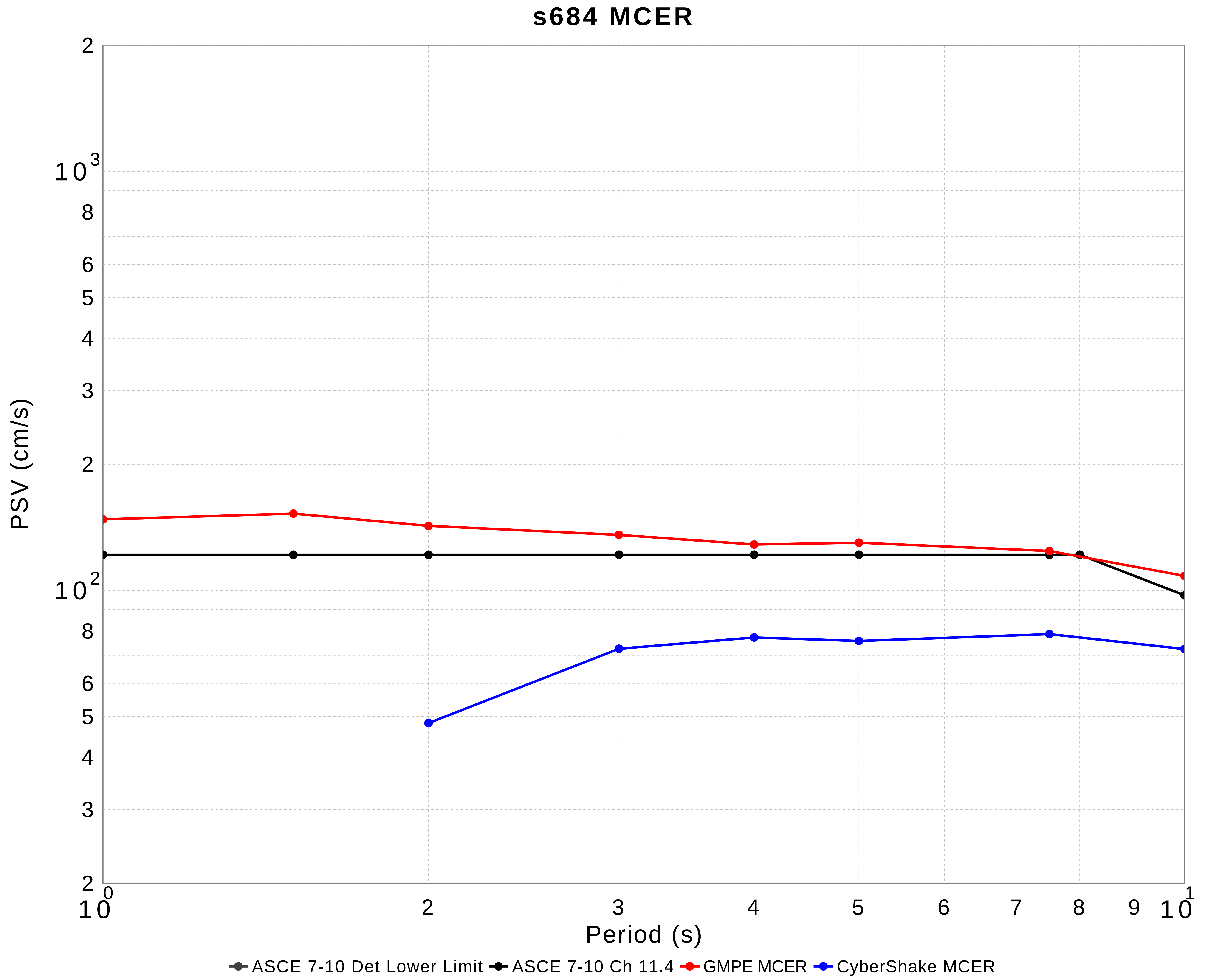

P22 MCER
PSV (cm/s)
Period (s)
2
10^3
8
6
5
4
3
2
10^2
8
6
5
4
3
2
10^0
2
3
4
5
6
7
8
9
10^1
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER

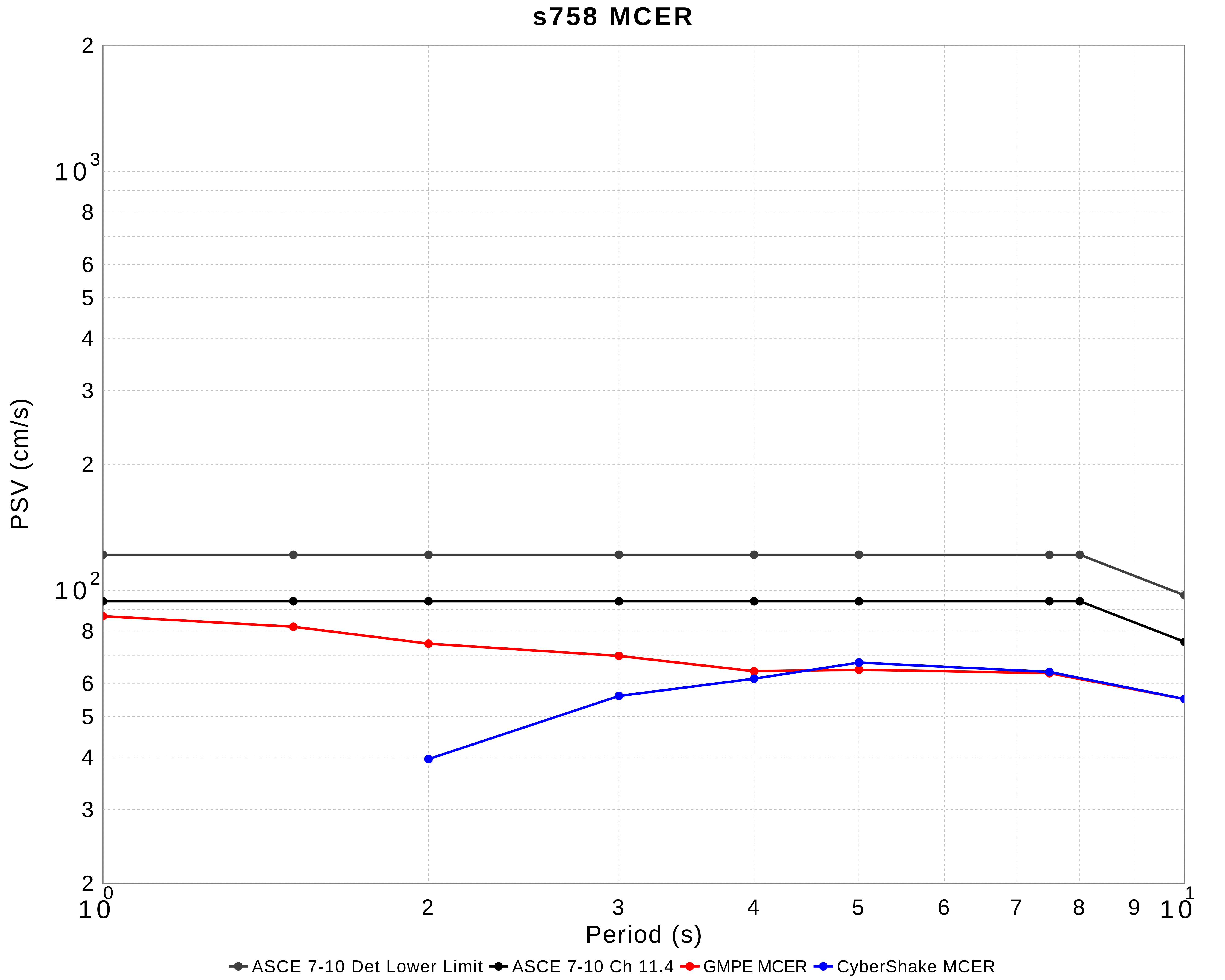

PAS MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER



s429 MCER
PSV (cm/s)
Period (s)
2
10^3
8
6
5
4
3
2
10^2
8
6
5
4
3
2
10^0
2
3
4
5
6
7
8
9
10^1
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER


s603 MCER
PSV (cm/s)
2
10^3
8
6
5
4
3
2
10^2
8
6
5
4
3
2
10^0
2
3
4
5
6
7
8
9
10^1
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER


s684 MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER



s758 MCER
PSV (cm/s)
Period (s)
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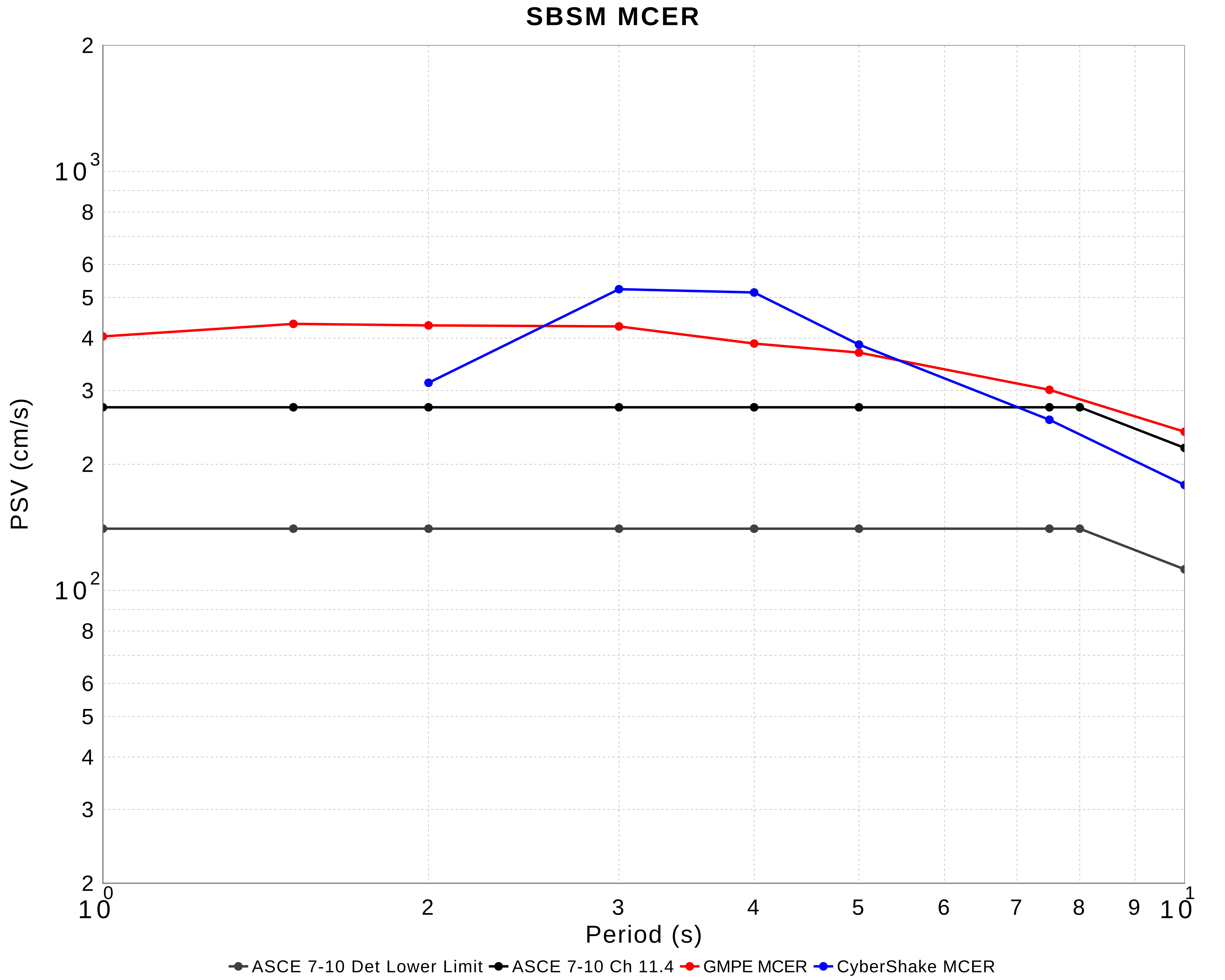
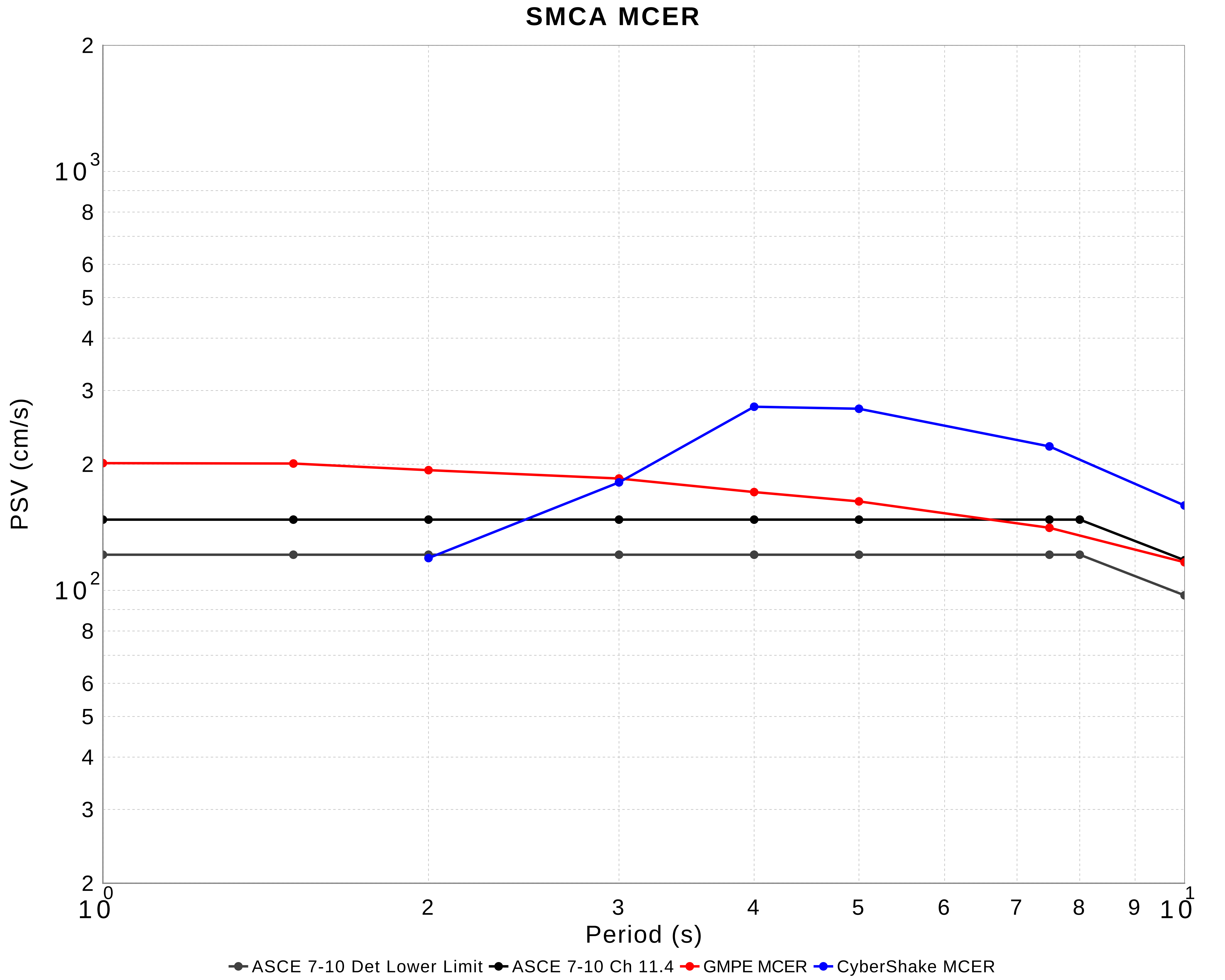
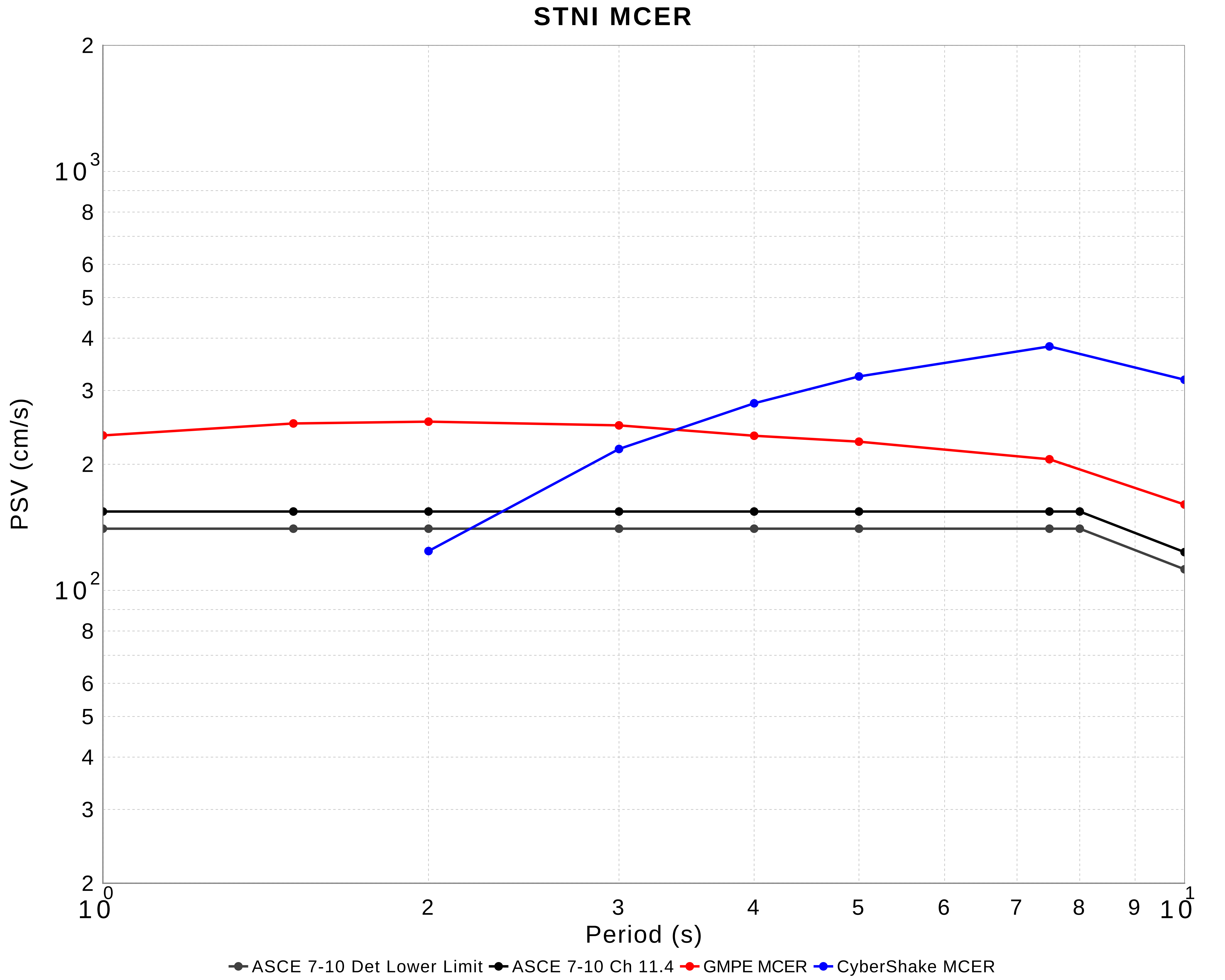
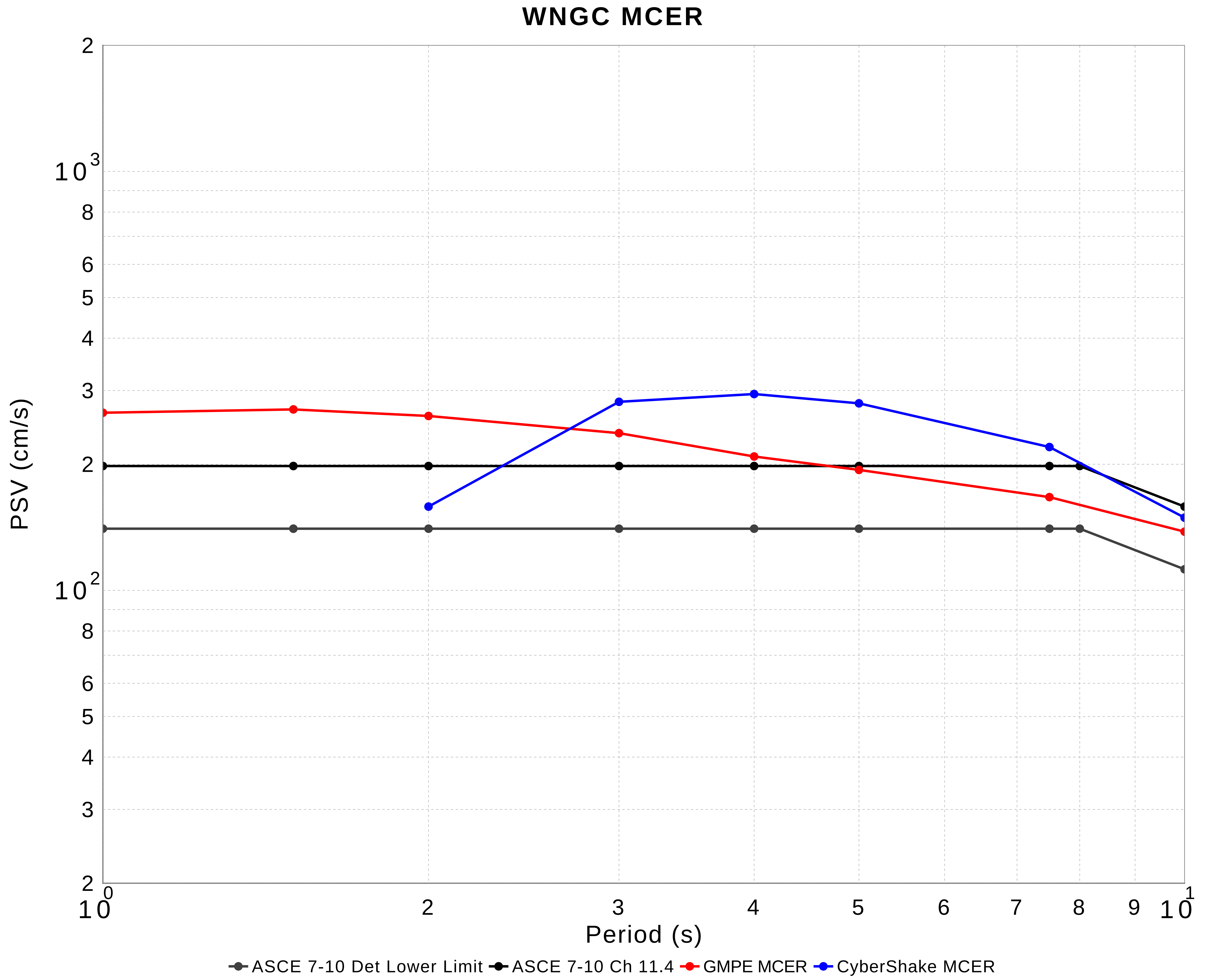
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER


SBSM MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER


SMCA MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER


STNI MCER
PSV (cm/s)
Period (s)
ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER


WNGC MCER
PSV (cm/s)
Period (s)
10^3
10^2
10^0
10^1
2
8
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6
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2
2
3
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ASCE 7-10 Det Lower Limit
ASCE 7-10 Ch 11.4
GMPE MCER
CyberShake MCER