Damage Survey and Analysis of the 20 May 2013 Newcastle-Moore, OK, EF-5 Tornado
Kiel Ortega\textsuperscript{1,2}, Donald Burgess\textsuperscript{1,2}, Gabriel Garfield\textsuperscript{1,3}, Christopher Karstens\textsuperscript{1,2}, James LaDue\textsuperscript{4}, Timothy Marshall\textsuperscript{5}, Tiffany Meyer\textsuperscript{1,4}, Brandon Smith\textsuperscript{1,2}, Richard Smith\textsuperscript{3}, Doug Speheger\textsuperscript{3}, and Gregory Stumpf\textsuperscript{1,6}  
\textsuperscript{1}Univ. Oklahoma/CIMMS  \textsuperscript{2}NOAA/OAR/NSRL \textsuperscript{3}NOAA/NWS/WFO OUN

\begin{itemize}
  \item \textbf{Path Start—Tornadic?}  
    \begin{itemize}
      \item Intermittent convergent path
      \item Anecdotal evidence of circulation on the ground
      \item Hints of debris via dual-polarized radar data
    \end{itemize}
  \item \textbf{Path Start—Non-Tornadic?}  
    \begin{itemize}
      \item Definitive video evidence not present until official start
      \item Lack of definite dual-pole debris signature until near official start
      \item Doppler velocity signature inbound-dominant, balanced over official start and path
    \end{itemize}
\end{itemize}

\textbf{Historical damage ratings of similar damage}  
(3 May 1999, 24 May 2011)

\textbf{Area near Moore Medical Center}  
\begin{itemize}
  \item Tornado looped (via PX-1000 radar data)
  \item Vehicles parked at Moore Medical Center thrown west into open field and southeast into the Emergency Room entrance
  \item One vehicle landed on top of the 2-story MMC
\end{itemize}

\textbf{Acknowledgments}  
The authors would like to thank the other surveyors and those who provided support during the survey: Tenya Brown, Kristin Cahoun, Chuck Dowell, John Ferrer, Jack Friedman, Daniel Kingfield, Patrick Marsh, Lori Redman, Adele Sears, Bruce Thoen, and Jeremy Warny. Thanks also to Jim Kirdson and the Advanced Radar Research Center for sharing PX-1000 images and loops. Additional thanks to all of the emergency responders, especially the Oklahoma Highway Patrol, Oklahoma City Police Department, Moore Police and Fire Departments, Norman Police Department and the Newcastle Fire Department, for their assistance in providing guidance (and a helicopter) to the survey teams and their tireless service in response to this tornado.

\textbf{Justify EF5}  
All had removal of some percentage of base plates
No capability to evaluate wall-to-roof connections
All had deficiencies w.r.t. WFCM
Wide bolt spacing, lack of clips for wall stud-to-base plate
5 surveyed EF-5 rated homes had toe-nailed connections for wall stud-to-base plate connections

\textbf{Justify EF4}  
Several were within tight gradients of damage (1 w/ across the street EF1 neighbor)

\textbf{Locations of Damage Survey Teams}  

\textbf{EF-5 rated home}  

\textbf{EF-4 rated home}  
Moore, OK – May 30, 2013

\textbf{EF-5 rated home}  
Tornado crossing I-44 at the Canadian River

\textbf{EF-4 rated home}  

\textbf{EF-5 rated home}  

\textbf{2 km}

\textbf{Pringles tank thrown 30 m}

\textbf{Oil tanks (5)
  \begin{itemize}
    \item Unknown dimension
  \end{itemize}

\textbf{Oil tanks brushed 30 m}

\textbf{ Öl tank thrown 30 m}

\textbf{Pineapple tank thrown 30 m}

\textbf{Path Start—Tornadic?}  

\textbf{Path Start—Non-Tornadic?}  

\textbf{Using DAT, surveyors relayed information back to WFO OUN in real-time for continuous updates of the tornado path and outline}  

\textbf{Early path data was used by private companies, like DirectTV, to modify billing}  

\textbf{Dept. of Health using high-resolution information to guide surveys}

\textbf{20 May 2013 EF-5 Tornado – DHIC TWR}

\textbf{Damage along dashed path officially entered into Storm Data at the University of Oklahoma}

\textbf{20 May 2013 EF-5 Tornado – OUN TWR}

\textbf{EF-5 rated homes}  

\textbf{EF-5 rated homes}  

\textbf{EF-5 rated homes}  

\textbf{EF-4 rated home}  

\textbf{History and damage}  

\begin{itemize}
  \item Historic damage ratings of similar damage  
    (3 May 1999, 24 May 2011)
  \end{itemize}

\textbf{Area near Moore Medical Center}  

\begin{itemize}
  \item Tornado looped (via PX-1000 radar data)
  \item Vehicles parked at Moore Medical Center thrown west into open field and southeast into the Emergency Room entrance
  \item One vehicle landed on top of the 2-story MMC
\end{itemize}

\textbf{Acknowledgments}  
The authors would like to thank the other surveyors and those who provided support during the survey: Tenya Brown, Kristin Cahoun, Chuck Dowell, John Ferrer, Jack Friedman, Daniel Kingfield, Patrick Marsh, Lori Redman, Adele Sears, Bruce Thoen, and Jeremy Warny. Thanks also to Jim Kirdson and the Advanced Radar Research Center for sharing PX-1000 images and loops. Additional thanks to all of the emergency responders, especially the Oklahoma Highway Patrol, Oklahoma City Police Department, Moore Police and Fire Departments, Norman Police Department and the Newcastle Fire Department, for their assistance in providing guidance (and a helicopter) to the survey teams and their tireless service in response to this tornado.

\textbf{Justify EF5}  
All had removal of some percentage of base plates
No capability to evaluate wall-to-roof connections
All had deficiencies w.r.t. WFCM
Wide bolt spacing, lack of clips for wall stud-to-base plate
5 surveyed EF-5 rated homes had toe-nailed connections for wall stud-to-base plate connections

\textbf{Justify EF4}  
Several were within tight gradients of damage (1 w/ across the street EF1 neighbor)